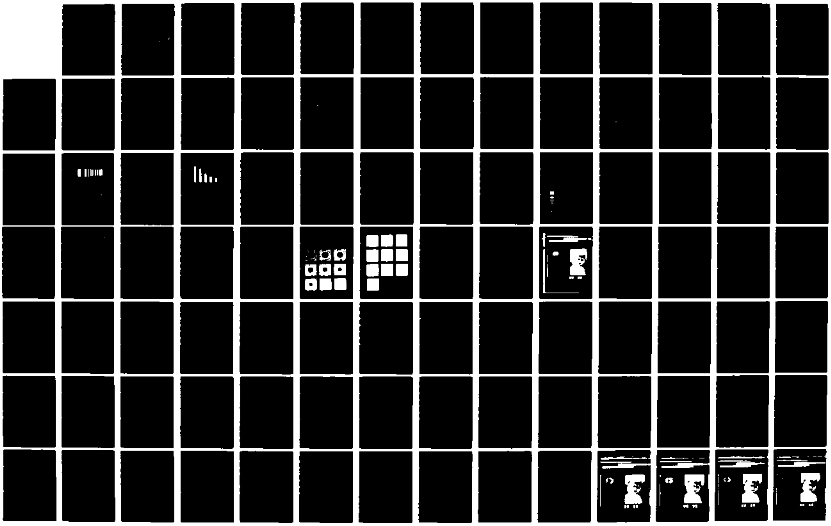
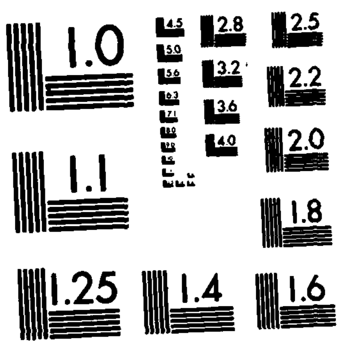
AD-A125 316 AUTOMATIC THRESHOLD DESIGN FOR A BOUND DOCUMENT SCANNER 1/3
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH
B J STANTON DEC 82 AFIT-CI/NR-82-71T

UNCLASSIFIED F/G 17/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A125316

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
AFIT/CI/NR 82-71T		

4. TITLE (and Subtitle) Automatic Threshold Design for a Bound Document Scanner	5. TYPE OF REPORT & PERIOD COVERED THESIS/DISSERTATION
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Bill James Stanton, Jr.	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: Massachusetts Institute of Technology	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433	12. REPORT DATE Dec 82
	13. NUMBER OF PAGES 218
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASS
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DTIC MAR 4 1983 H

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-17

17 Feb 83

LYNN E. WOLAVER
Dean for Research and
Professional Development
AFIT, Wright-Patterson AFB OH

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATTACHED

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DTIC FILE COPY

83 03 03 050

AUTOMATIC THRESHOLD DESIGN FOR A

BOUND DOCUMENT SCANNER

by

BILL JAMES STANTON, JR

Captain, United States Air Force

Submitted to the Department of Electrical Engineering and Computer Science August 1982 in partial fulfillment of the requirements for the Degree of Master of Science in Electrical Engineering

ABSTRACT

Research was carried out on an electro-optical bound document scanner using a charge-coupled device (CCD) as a sensing element. The goal was to develop a means whereby the voltage threshold level of the video analog-to-digital converter could be set automatically to provide optimum hard-copy output over a range of lighting conditions and document background colors and qualities. To determine an acceptable component of the analog video signal as a thresholding reference, an extensive study of the signal behavior was conducted over a variety of conditions.

An Automatic Threshold Control (ATC) was designed that exploited the modulation transfer function of the CCD's analog signal. A CALIBRATION PATTERN is superimposed at the left-hand margin of the page being scanned. This pattern contains various discrete spatial frequencies. The threshold voltage is varied automatically until the number of black/white (zero/one) transitions is maximized for the CALIBRATION PATTERN. The threshold voltage producing this maximum number of transitions is equivalent to the threshold required to produce optimum resolution in the scanner hard-copy output. This threshold value is then locked in for the duration of the page being scanned.

System performance using this ATC scheme is excellent. The scanner selects a threshold voltage on a per-page basis that yields acceptable copies. The ATC is able to automatically compensate for various types of paper and changes in lighting conditions due to fluorescent tube deterioration. Slightly less than optimum thresholding may occur about 10 to 15 percent of the time, but this is due to data uncertainty and other shortcomings in the scanner rather than in the ATC scheme. (Page count: 224)

Thesis Supervisor: Dr. J. F. Reintjes
Title: Professor Emeritus, Electrical Engineering

AFIT/CI/NR 82-71T

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to ascertain the value and/or contribution of research accomplished by students or faculty of the Air Force Institute of Technology (ATC). It would be greatly appreciated if you would complete the following questionnaire and return it to:

AFIT/NR
Wright-Patterson AFB OH 45433

RESEARCH TITLE: Automatic Threshold Design for a Bound Document Scanner

AUTHOR: Bill James Stanton, Jr.

RESEARCH ASSESSMENT QUESTIONS:

1. Did this research contribute to a current Air Force project?

( ) a. YES ( ) b. NO

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not?

( ) a. YES ( ) b. NO

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency achieved/received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

( ) a. MAN-YEARS ________ ( ) b. $________

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3. above), what is your estimate of its significance?

( ) a. HIGHLY SIGNIFICANT ( ) b. SIGNIFICANT ( ) c. SLIGHTLY SIGNIFICANT ( ) d. OF NO SIGNIFICANCE

5. AFIT welcomes any further comments you may have on the above questions, or any additional details concerning the current application, future potential, or other value of this research. Please use the bottom part of this questionnaire for your statement(s).

NAME GRADE POSITION

ORGANIZATION LOCATION

STATEMENT(s):

AUTOMATIC THRESHOLD DESIGN FOR A BOUND DOCUMENT SCANNER

by

BILL JAMES STANTON, Jr

Captain, United States Air Force

S. B., United States Air Force Academy
Electrical Engineering (1973)

Submitted to the Department of Electrical
Engineering and Computer Science
in Partial Fulfillment for
the Degree of

MASTER OF SCIENCE IN

ELECTRICAL ENGINEERING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

December 1982

Signature of Author Bill J Stanton
Dept of EECS, August 1982

Certified by J F Reintjes
J. F. Reintjes, Thesis Supervisor

Accepted by
Chairman, Departmental Graduate Committee

To Donna, Spencer, and Stuart

AUTOMATIC THRESHOLD DESIGN FOR A

BOUND DOCUMENT SCANNER

by

BILL JAMES STANTON, JR

Captain, United States Air Force

Submitted to the Department of Electrical Engineering and Computer Science August 1982 in partial fulfillment of the requirements for the Degree of Master of Science in Electrical Engineering

ABSTRACT

Research was carried out on an electro-optical bound document scanner using a charge-coupled device (CCD) as a sensing element. The goal was to develop a means whereby the voltage threshold level of the video analog-to-digital converter could be set automatically to provide optimum hard-copy output over a range of lighting conditions and document background colors and qualities. To determine an acceptable component of the analog video signal as a thresholding reference, an extensive study of the signal behavior was conducted over a variety of conditions.

An Automatic Threshold Control (ATC) was designed that exploited the modulation transfer function of the CCD's analog signal. A CALIBRATION PATTERN is superimposed at the left-hand margin of the page being scanned. This pattern contains various discrete spatial frequencies. The threshold voltage is varied automatically until the number of black/white (zero/one) transitions is maximized for the CALIBRATION PATTERN. The threshold voltage producing this maximum number of transitions is equivalent to the threshold required to produce optimum resolution in the scanner hard-copy output. This threshold value is then locked in for the duration of the page being scanned.

System performance using this ATC scheme is excellent. The scanner selects a threshold voltage on a per-page basis that yields acceptable copies. The ATC is able to automatically compensate for various types of paper and changes in lighting conditions due to fluorescent tube deterioration. Slightly less than optimum thresholding may occur about 10 to 15 percent of the time, but this is due to data uncertainty and other shortcomings in the scanner rather than in the ATC scheme. (Page count: 224)

Thesis Supervisor: Dr. J. F. Reintjes
Title: Professor Emeritus, Electrical Engineering

TABLE OF CONTENTS

Table of Contents

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to Professor J. F. Reintjes for his steadfast assistance throughout the course of this research. He promoted an atmosphere of complete academic freedom which was a pleasure to experience. I would also like to mention my deep gratitude to my wife for her unfailing support and patience in the preparation of the manuscript. The task of completing this thesis would have been much more difficult without her contributions.

BIOGRAPHICAL NOTE

B. J. Stanton, a Captain in the U. S. Air Force, is a distinguished graduate of the U. S. Air Force Academy, Class of 1973. As an undergraduate, his work included research in the security of defense communications systems. He completed Undergraduate Pilot Training with top honors in 1974 and Advanced Fighter Training in 1975. He served as an F4D Aircraft Commander and Wing Weapons and Tactics Officer at Royal Air Force Base Woodbridge, England from 1975 to 1978. During that time he participated in joint NATO Force exercises and taught laser weapon tactics. From 1978 to 1981 he served as an AT-38B fighter instructor pilot and academic instructor. His duties included aerial instruction in basic and advanced fighter maneuvers, surface attack tactics, low-level ingress techniques, and various tactical formations. Additionally, he was responsible for significant phases of the surface attack academic curriculum. He is an experienced fighter pilot with 1125 hours of flying time.

LIST OF FIGURES

List of Figures

List of Figures

SYMBOLS AND ABBREVIATIONS

AC	Alternating Current
ATC	Automatic Threshold Control
CALIBRATION PATTERN	Series of black and white line-pairs of varying thicknesses used to generate a specific analog video waveform for threshold-setting purposes
CCD	Charge Coupled Device
DC	Direct Current
ECP	Experimental Calibration Pattern
EOPS	Electro-Optical Page Scanner; also the mnemonic used to describe the complete F8 software package for the scanner
F8	Designation of the microprocessor used with the scanner for various control functions; complete nomenclature is: Fairchild F8 Formulator
ISE	Image Sensing Element
MTC	Maximum value of VTC obtained from scanning a particular Calibration Pattern
N	Decimal equivalent of the value supplied by the F8 to the Threshold Level Generator to produce a specific threshold voltage
Np	Value of N generating the maximum value of VTC in a given series of samples
Pass	The act of taking seven samples of VTC at N-values that are separated by a fixed step size
Pel Swing	Positive difference between the black and white voltage levels in the analog video signal

Symbols and Abbreviations

QSET	Mnemonic used for the algorithm that picks the optimum threshold value by taking four sets of seven samples per set with each set using a progressively smaller sampling increment of N
R	Reduced range of N-values that have been defined from the results of the previous pass of the algorithm QSET; the reduced range R is that range sampled on the next pass of QSET
RV	Span of values of N producing significant VTC values (where significant is defined as VTC > 1)
S1	Step size used to increment the value of N while taking VTC samples in the first pass of the algorithm QSET; subsequent passes use step sizes labeled in sequence: S2, S3, S4
TLG	Threshold Level Generator
Vref	Output of op amp U3 of the Threshold Level Generator; used as the reference voltage for the 10-bit D-to-A converter
V2	Output of op amp U2 of the Threshold Level Generator; represents the inverted fraction of V2 as determined by the quotient (N/1024)
V0	Voltage output of the Threshold Level Generator
VTC	Video Transition Count: the sum of digitized video black/white transitions encountered in one scan line for a given threshold value

CHAPTER 1

INTRODUCTION

A. PROBLEM STATEMENT

The goal of this research was to refine an existing electro-optical bound document scanner under development in the Laboratory for Information and Decision Systems by reducing the need for manual adjustments. Specifically this involved designing and incorporating a means of automatically setting the voltage threshold level of the video one-bit analog-to-digital converter at a value that would provide optimum quality in the reproduced copy. The subsystem accomplishing this task will be referred to as an Automatic Threshold Control, or ATC in this report. A further objective of the ATC was to provide the scanner with the capacity for automatically compensating for paper color and/or quality and for variations in illumination.

B. PROJECT BACKGROUND

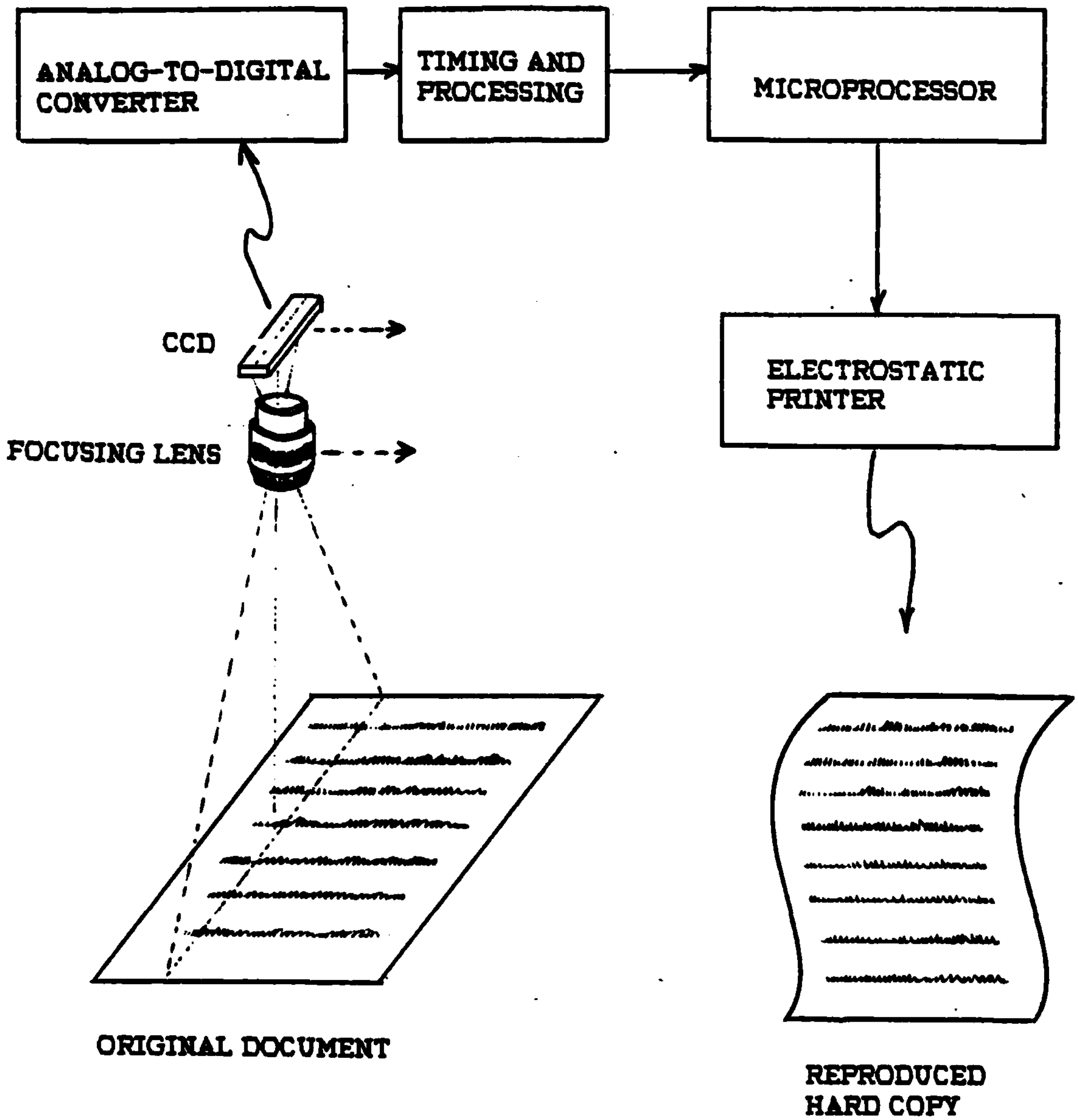
The immediate thrust behind the development of a bound document scanner at the Laboratory for Information and Decision Systems is to improve the interlibrary resource sharing process which now works on a "lending-borrowing" principle. The requirement to physically move either originals or copies from one geographic location to another can take up to two to four weeks from the initial request. On the other hand, the ability to electronically move hard copy material economically would essentially reduce turn-around time to only that required to process the request, locate the document, and transmit the

specified pages. Conceivably, turn-around time could be reduced to less than a day, and in many cases less than one hour. In addition, the follow-on applications of such a system in commercial, industrial, and military areas could result in significant increases in efficiency of information management.

The principle of the bound document scanner to which the ATC will be applied is to convert the information content of an 8.5 x 11 inch printed page into 3.6 megabits of digital information through line-by-line scanning. The digital signal can then be compressed for transmission on a 56 kilobit/second data line, such a line representing a tradeoff between transmission cost and per-page transmission time. Copy is produced at the destination by an electrostatic printer.

In the laboratory, scanning is accomplished by a system that uses a Fairchild Charge Coupled Device (CCD) to convert light to analog electrical signals. The CCD consists of a linear array of 2048 image sensing elements (ISEs). The output of each element is proportional to the intensity of light and integration time allowed. One "line" of information is obtained in parallel form and then shifted out of the CCD serially for subsequent processing. The CCD, light source, and focusing lens are mounted on a common structure and physically moved in the second dimension by a phase-locked loop DC motor to provide a raster scan of the entire page.

Several theses have been written concerning the bound document scanner either directly or indirectly. They are listed



SIMPLIFIED BLOCK DIAGRAM OF
THE BOUND DOCUMENT SCANNER

FIGURE 1.1

in Chapter 7, but they also deserve mentioning now for those interested in more extensive background review. Aghamohammadi conducted the original design and fabrication of the bound document scanner. If a working knowledge of the scanner is required, his thesis should be read and thoroughly understood before proceeding. Keverian, while primarily concerned with a parallel project on microfiche scanning, developed hardware interfaces with the F8 microprocessor available in the laboratory. These interfaces are used in the bound document scanner system. Agudelo worked on a document cradle, light non-uniformity, and other problems associated with the existing scanner. Medley accomplished extensive software and hardware modifications to the F8 microprocessor independent of any other projects supported by the F8. His thesis should be reviewed when information concerning current operation of the F8 is required. Vinciguerra studied the feasibility of various data compression schemes for application to document transmission, and Dishop followed this work with further evaluation and design.

C. RESEARCH PLAN

The first phase of this research consisted of analyzing the analog video signal behavior with respect to various light conditions, paper reflectivities, and spatial frequency excitation. The objective was to pinpoint critical variables that would be suitable for obtaining a proper threshold relation. In the second phase, a subsystem was designed and built that would sense the video signal variable and control the voltage

threshold level according to the performance of this variable. Finally, the system was evaluated with different lighting conditions, paper colors, and spatial frequency patterns to determine its feasibility.

D. SUMMARY OF RESULTS

An ATC was designed that exploited the modulation transfer function of the CCD as a means for selecting an optimum voltage threshold level. A CALIBRATION PATTERN consisting of several sets of parallel lines is superimposed at the left-hand margin of the page being scanned. This pattern contains various discrete spatial frequencies. The threshold voltage is varied automatically until the number of black/white transitions is maximized for the CALIBRATION PATTERN. The threshold voltage producing this maximum number of transitions is then locked in for the duration of the page being scanned.

System performance using this ATC scheme has been excellent. The scanner now selects a threshold voltage on a per-page basis that yields acceptable copies. The ATC is able to automatically compensate for various types of paper and changes in lighting conditions due to fluorescent tube deterioration. Thresholding errors occur about 10 to 15 percent of the time, but they are due to other shortcomings in the scanner rather than in the ATC scheme. When threshold errors do not occur, the threshold chosen is the best that can be obtained.

E. PREVIEW OF DISCUSSION

Chapter 2 presents an analysis of the analog video waveforms that are derived from the CCD under operational conditions. The results of this analysis are used to develop a conceptual approach to automatic threshold control. Chapter 3 discusses the evaluation of various experimental CALIBRATION PATTERNS to determine the characteristics necessary to produce the desired analog video waveform for thresholding purposes. A practical implementation of tne ATC is developed in Chapter 4, together with considerations that led to the implementation. Chapter 5 contains the development of sampling algorithms that allow the thresholding process to be accomplished in minimum time along with the incorporation of these algorithms into the existing scanner software. Finally the results, conclusions, and recommendations for further research are detailed in Chapter 6.

CHAPTER 2

ANALOG VIDEO SIGNAL ANALYSIS

A. OBJECTIVE

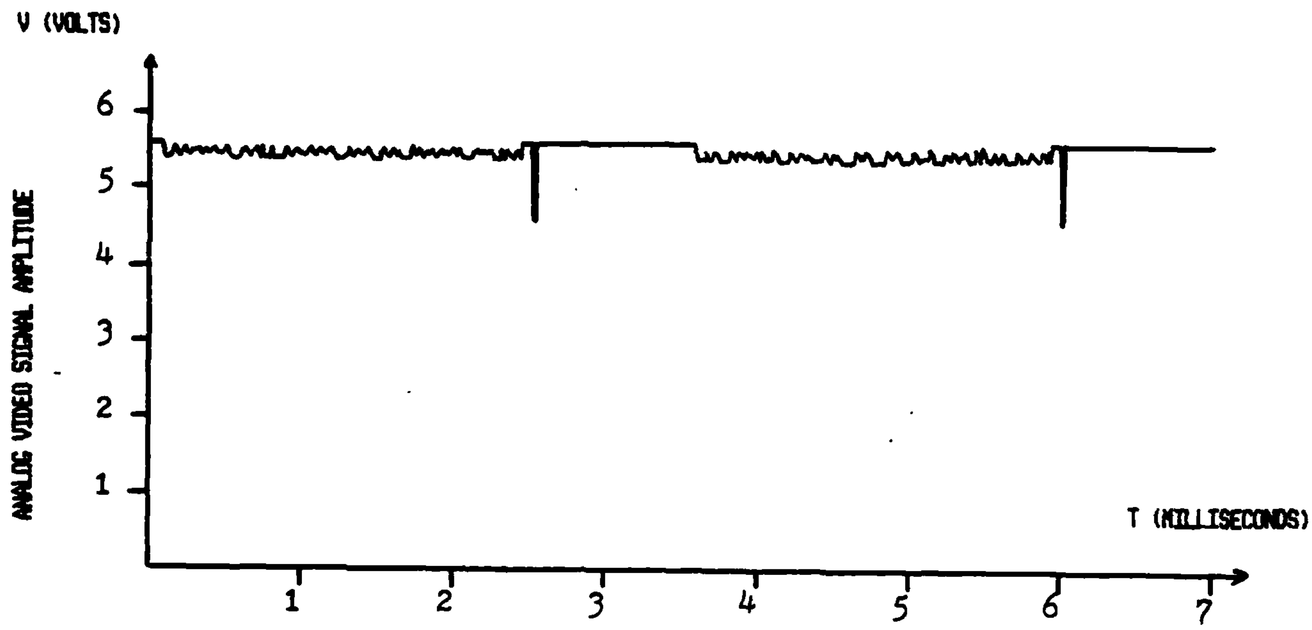
A thorough analysis of the analog video signal derived from the CCD during the line-scanning process was conducted to classify its components and learn its behavior under different conditions. The purpose was to develop a sound basis for selecting a parameter of this signal for use in controlling the voltage threshold level of the A-to-D converter. Ultimately, the analog video signal is dependent on the amount of light reaching the individual image sensing elements (ISEs) of the CCD. Many factors affect the amount of light that the CCD sees, but the relevant factors are those that normally occur in a "user environment", rather than abnormal conditions that could be induced in a "laboratory environment". The factors researched were:

1. Intensity of the light source (1)
2. Color content of the document
3. Spatial-frequency content of the document

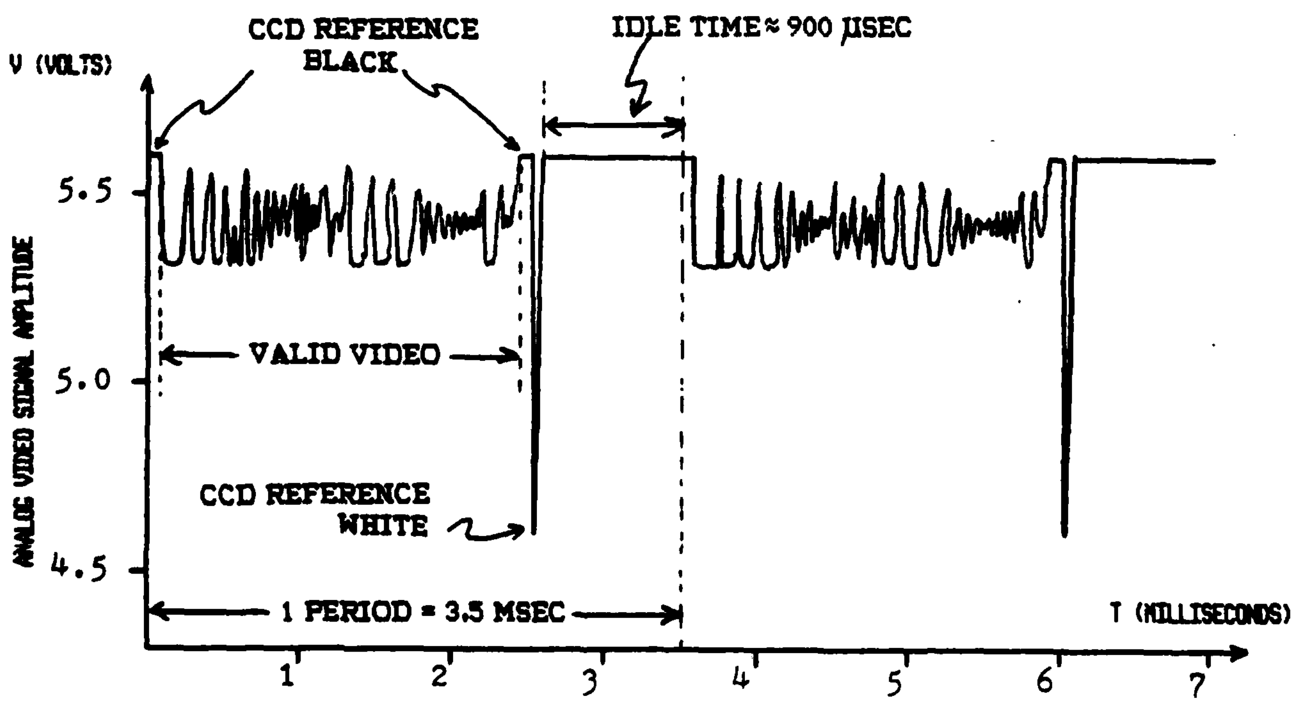
B. FINDINGS

The general configuration of the analog video signal will first be described with reference to Figure 2.1 and the CCD142 data in Appendix A. One period of the signal is equivalent to

(1) Note that the distance between the document and the CCD also affects the amount of light reaching the ISEs. This fact, due to the optics and the geometry of the scanner, gives rise to a light non-uniformity issue which was addressed by Agudelo. Additional information on this subject is included in Chapter 6.



(A) TWO PERIODS OF THE CCD ANALOG VIDEO SIGNAL



(B) EXPANDED SCALE OF AC COMPONENT

FIGURE 2.1

one line of video information. In turn, the period is controlled by the signal, EXTERNAL EXPOSURE (1) which initiates the dump of data from the CCD. The CCD analog data stream for one line is in the following order: black reference level, valid video, black reference level, and white reference level. Once the CCD data dump is complete, there are almost 900 microseconds of idle time to allow for microprocessor command functions. In terms of magnitude, the video information is contained in an AC component obtained by subtracting the instantaneous total analog voltage from a fixed DC component of 5.6 volts. The maximum voltage of 5.6 volts represents absolute black, and negative departures from this maximum result from various light levels absorbed by the CCD ISEs. The CCD typically saturates at 1400 millivolts below absolute black, and the fluorescent lights used as the illumination source provide ample output to drive the CCD to saturation. But in the current design, the focusing lens f-stop is set at 5.6 for depth-of-field considerations. This resulted in the largest white levels observed being 200 to 300 millivolts below black, depending on the condition of the lights. In other words, the existing combination of illumination source and f-stop setting drives the CCD at 14 to 21 percent of its capacity. Valid video information therefore was found in the extreme to reside in the range 5.3 to 5.6 volts and more commonly in the range 5.4 to 5.6 volts. The major issue of setting the proper

(1) Reference Aghamohammadi, Chapter 6 and TIMING AND PROCESSING circuit, Appendix E.

threshold level is finding the value of voltage that is LESS THAN all black voltage values and GREATER THAN all white voltage values. For this purpose, it is important to understand how the black and white video levels react to the factors listed above. First, however, it will be convenient to introduce the term "pel swing," defined as the magnitude of the DIFFERENCE between black and white voltage levels in the video signal. Pel swing is normally measured in millivolts and provides a convenient quantity for expressing the analog signal behavior.

That light intensity has a predictable effect on pel swing was easily demonstrated by varying the f-stop of the focusing lens. A blank piece of white paper was scanned with soft white fluorescent lights providing illumination. Pel swing was measured from absolute black (5.6 volts) to the maximum deviation from absolute black. The results are illustrated in Figure 2.2. Note that f-stops of 2.8 and below saturate the CCD.

The background color of the document being scanned is also an important parameter because in a user environment the scanner will certainly encounter different qualities and textures of white paper and, less commonly, a variety of paper colors. CCD response to paper color and texture at a fixed f-stop of 5.6 was measured experimentally by scanning a blank piece of construction paper of a uniform color and recording the pel swing from absolute black to the maximum deviation. Again, soft white fluorescents were used. These results are shown in Figure 2.3. In a predictable fashion, white and black paper yield the two

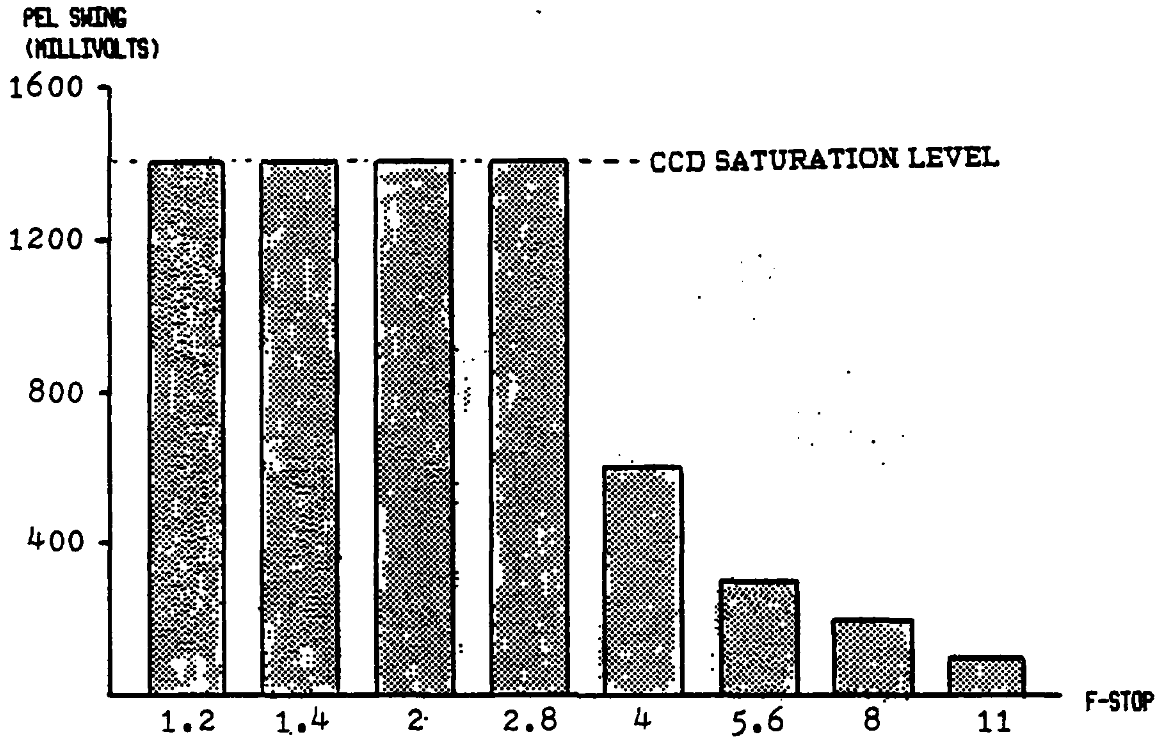


FIGURE 2.2 PEL SWING VERSUS LIGHT INTENSITY AS CONTROLLED BY THE FOCUSING LENS F-STOP

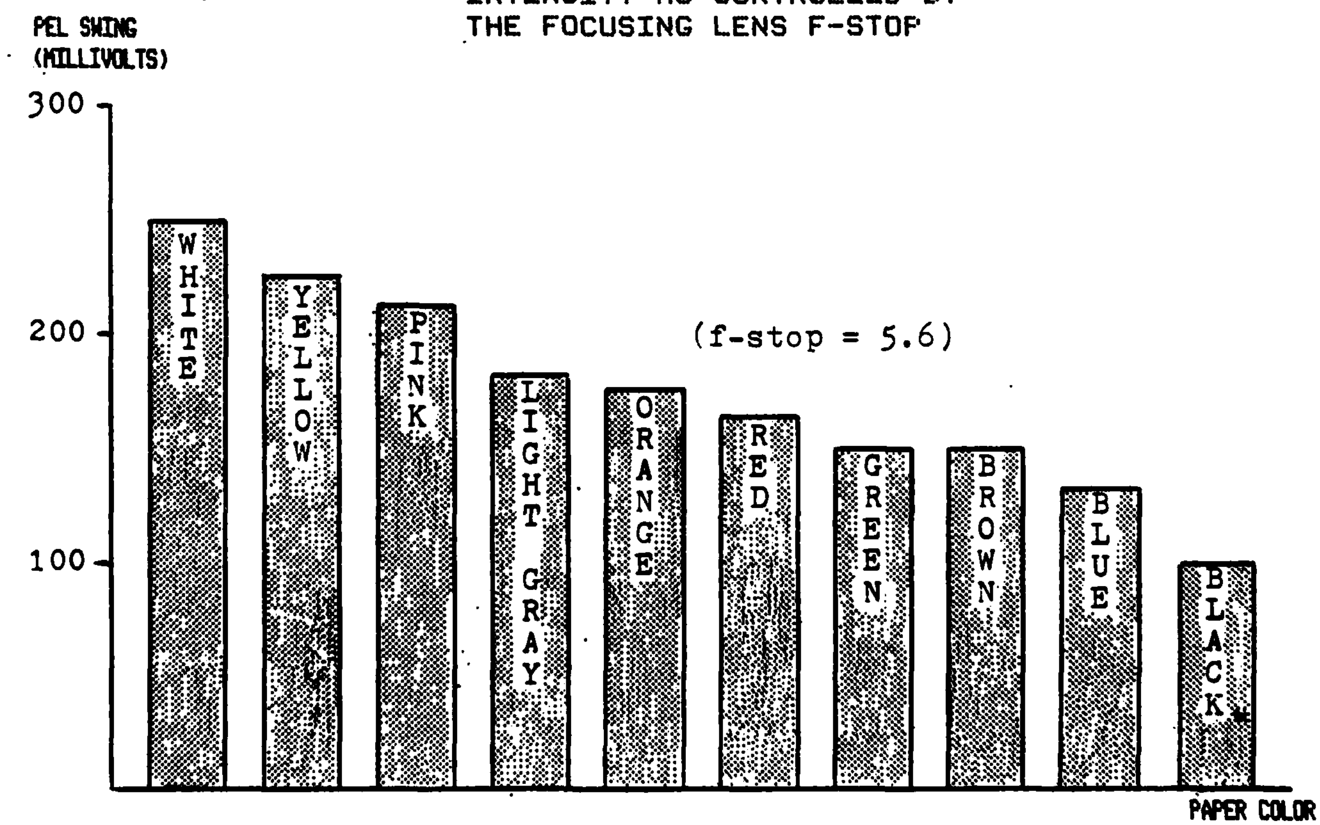
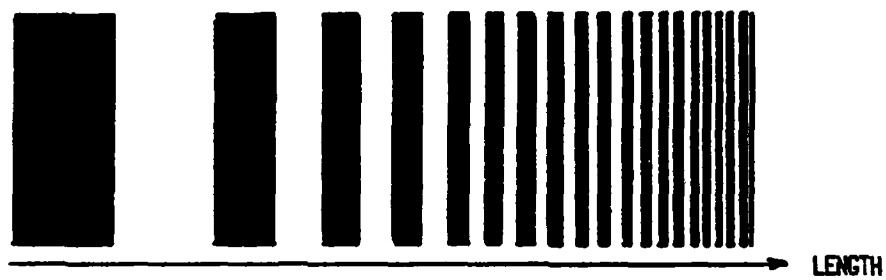


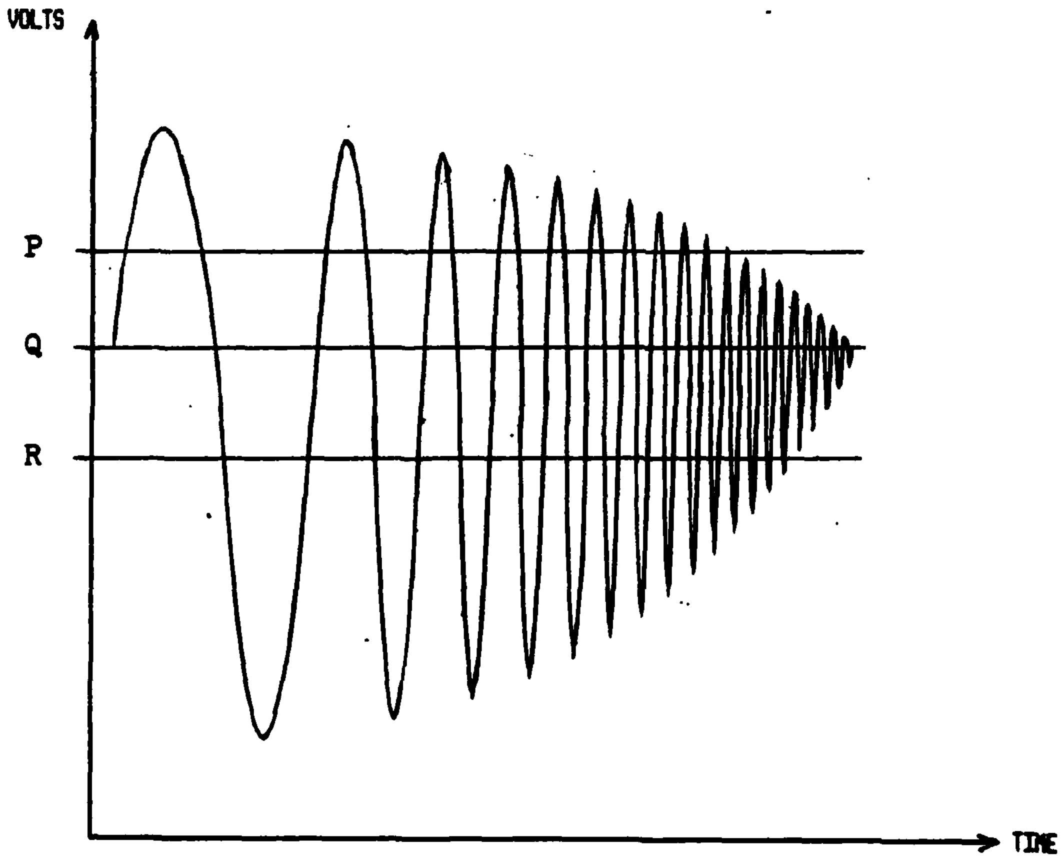
FIGURE 2.3 PEL SWING VERSUS PAPER COLOR

extremes in the range of pel swings. But from a more critical standpoint, one would expect the resulting analog signal from scanning black paper to be very close to absolute black, that is, to yield a very small pel swing. However, this experiment revealed considerable pel swing with black paper. The cause was traced to stray light "leaking" to the CCD ISEs due to a design deficiency in the scanner's optical path. This problem is covered in Chapter 6.

The behavior of the video signal with respect to spatial-frequency content of the information contained on a page is a more complicated issue. As stated above, pel swing has been measured between absolute black and the maximum white level generated by the CCD under blank, monochromatic paper conditions (zero spatial frequency). But with increases in spatial frequency information on the page resulting from alternating black and white lines, signals corresponding to the black level migrate downward away from absolute black, while signals corresponding to the white level migrate upward although not at the same rate. Figure 2.4 illustrates this behavior by showing the CCD response to a series of black lines and white spaces that represent increasing spatial frequency. This phenomenon is due to "crosstalk" between ISEs in the form of hole-electron spillovers. In other words, when one ISE is excited while an adjacent ISE is not excited, there tends to be a certain amount of charge transfer between the two ISEs. The result is less signal output from the principal ISE and a small signal output from adjacent



(A) SERIES OF LINES AND SPACES
REPRESENTING INCREASING
SPATIAL FREQUENCY



(B) ANALOG VIDEO SIGNAL RESULTING
FROM SCANNING LINES IN (A)

FIGURE 2.4

ISEs, and this is exhibited in the modulation transfer function discussed in Appendix A. For the CCD142 in this particular application, a spatial frequency of 100, equivalent to a resolution of 200 lines on the scanned document, will produce the Nyquist rate at the face of the CCD. The Nyquist rate is defined as the spatial frequency that will excite every other ISE in the CCD's linear array. Hence, it is the maximum spatial frequency the CCD is physically capable of resolving. Experimental measurements of pel swing versus spatial frequency are displayed in Figure 2.5. The measurements of black and white level migrations as a function of spatial frequency are presented in Figure 2.6. It is important to understand the relationship among Figures 2.4 to 2.6. First observe the fact that the curves in Figure 2.6 exactly form the envelope of the waveform of Figure 2.4. (1) Also note in Figure 2.6 that the vertical distance between the two curves at a particular spatial frequency is precisely the pel swing generated by that spatial frequency as pictured in Figure 2.5.

The results presented thus far are correct in showing the general trend of analog signal behavior, but the data have limited accuracy for a number of reasons. One reason already cited is the stray light leakage which has the effect of inducing unwanted bias signals. Another reason is the fact that the analog signal contains 30 to 50 millivolts of clocking noise

(1) The apparent curving envelope in Figure 2.4 is due to a scaling factor in the computer generation of the waveform.

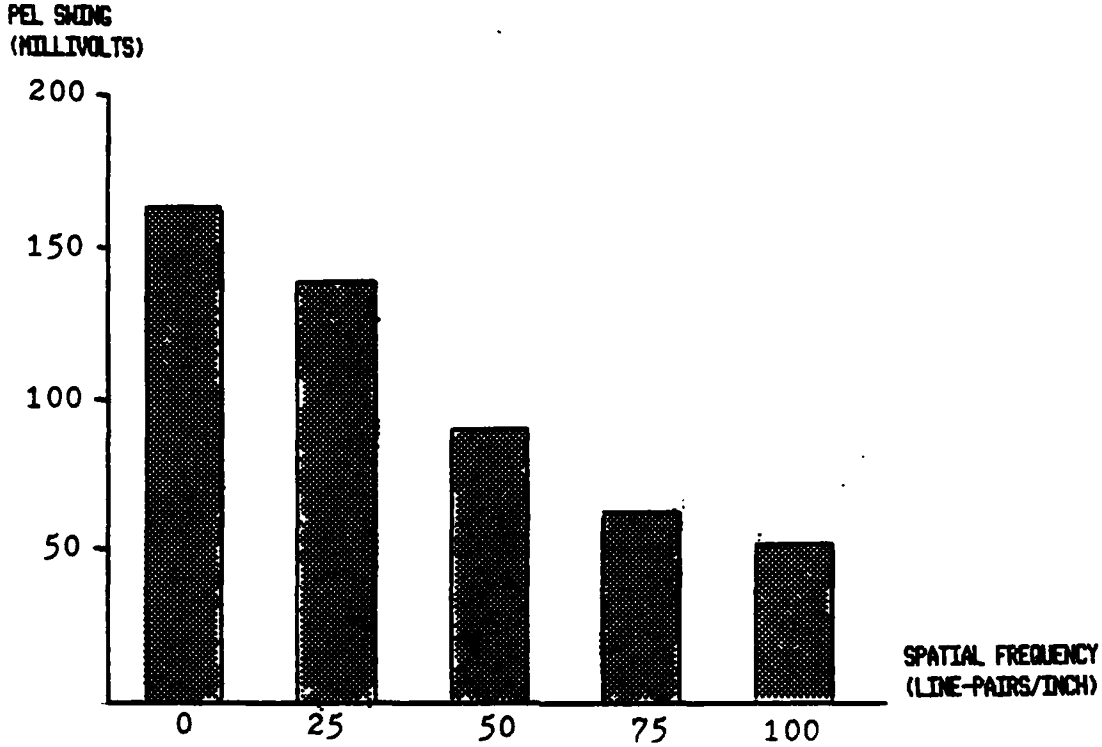


FIGURE 2.5 PEL SWING VERSUS SPATIAL FREQUENCY

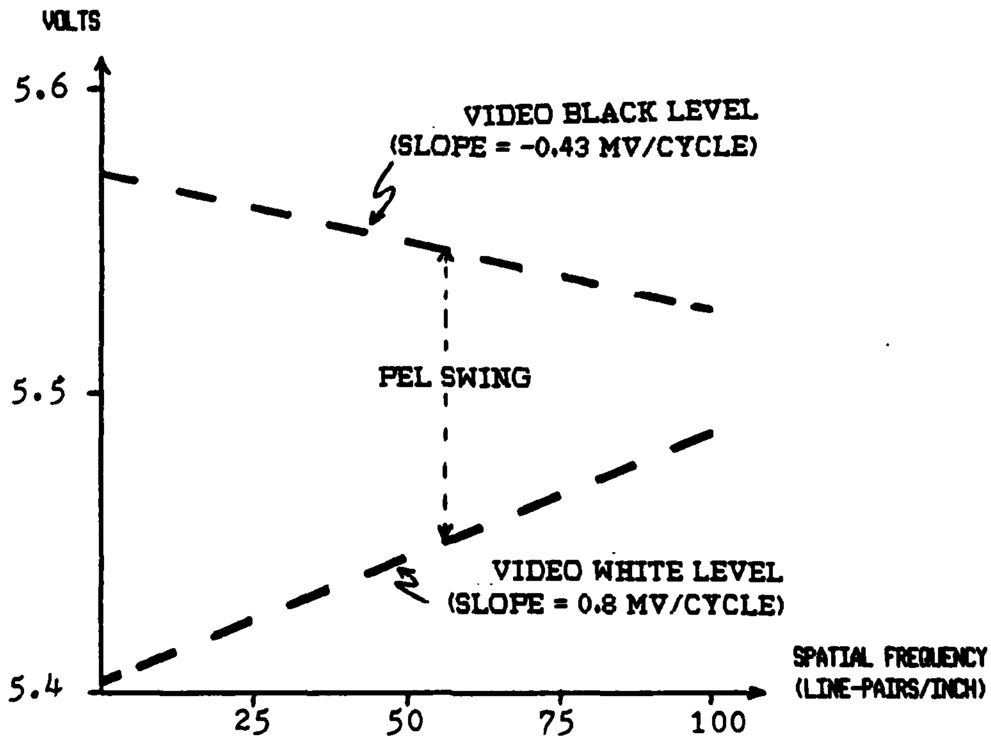


FIGURE 2.6 BLACK AND WHITE ANALOG VIDEO LEVELS VERSUS SPATIAL FREQUENCY

which makes precise measurements extremely difficult to obtain. A third reason stems from the deterioration of fluorescent lights with time, causing slightly different light levels from day to day. Despite these uncertainties, however, adequate information had been obtained at this point to proceed with the ATC design.

C. CHOICE OF PARAMETER FOR THRESHOLD CONTROL

Recall from Chapter 1 that the threshold value being sought is that which will enable the scanner to give the highest quality output possible. Output quality can be measured by "resolution" or the ability to resolve a set of alternating black and white lines of equal width. The more lines/unit length of the ensemble the scanner can resolve, the better will be the quality of the output. Resolution, in turn, is directly related to spatial frequency. Therefore, it can be said that the desired threshold level is one that will digitize all spatial frequencies represented in the analog video signal thereby producing the highest resolution in the output. With the goal now defined as preserving all spatial frequencies as the video signal is digitized, it is logical to exploit the analog video-signal behavior with respect to spatial frequency as the parameter for controlling the threshold. The concept is more easily understood by the following example.

Referring back to Figure 2.4, if one were required to select a threshold voltage that would permit proper digitization of all alternations between black and white, one should choose voltage-level Q as the correct value. Other threshold levels

such as P or R would cause loss of the higher spatial-frequency information in the A-to-D conversion process. This leads to a simple algorithm for selecting the optimum threshold, using the particular analog signal of Figure 2.4:

1. Vary the A-to-D threshold voltage through an appropriate range of discrete values.
2. Count the number of zero/one (black/white) transitions at each discrete threshold value.
3. Select the threshold value that resulted in the maximum number of black/white transitions.

It is important to highlight the fact that, for threshold-setting purposes, use of an analog video signal containing linearly increasing spatial frequencies is fundamental to the success of the algorithm. A signal such as this must be obtained by scanning a CALIBRATION PATTERN such as that shown in Figure 2.4(A). Issues concerning choice of a CALIBRATION PATTERN will be discussed in Chapter 3.

D. PARAMETERS REJECTED FOR THRESHOLD CONTROL

Other options that were considered but not chosen for threshold control include:

1. Video white and black levels
2. CCD reference white and black levels
3. Combinations of the above

Use of one of the above parameters would have been in the context of a real-time threshold control scheme; that is, one that would have continuously modified the threshold level based on incoming video information. In general, controlling the threshold level by direct reference to a particular voltage value of the time-varying video signal was explored but rejected due to the

complexity involved in extracting the required information from the video signal. The clocking noise in the video signal, relatively long durations of white signal, and the migration of the white and black signal levels toward each other as the spatial frequency of the textual patterns increases, all complicate the task of pinpointing a particular level of video signal. Further complexities arise in selecting a video level or combination of video levels that would provide a stable reference for selecting an optimum threshold value. A relatively simple method of detecting both peak white and black levels of the time-varying video signals and then averaging the two for a correct threshold level was also deemed unfeasible due to the different migration rates (1) of the black and white levels, and due to the video signal normally containing substantially more white information than black information. Finally, using the CCD reference white and black levels was eliminated from consideration because these levels contained no information about light intensity, paper reflectivity, or spatial frequency content of the document.

(1) Note the absolute values of the slopes of the two curves in Figure 2.6 are different.

CHAPTER 3

CALIBRATION PATTERN EVALUATION

As implied in Chapter 2, the term CALIBRATION PATTERN will be used in this thesis to denote a series of parallel black and white lines for forcing the CCD to produce a specific analog video signal for threshold-setting purposes. The design of the ATC calls for the CALIBRATION PATTERN to be located in the left-hand margin of the document being scanned. During a normal scanning sequence, the first lines that the scanner sees would be those of the CALIBRATION PATTERN. Transmission of video information to the printer would be inhibited until the threshold-setting sequence is complete.

Optimally, the CALIBRATION PATTERN should consist of black lines on a transparent surface, thereby allowing the margin of the document being scanned to provide the background. This would permit the analog video signal to be indicative of the characteristics of the paper being scanned, and in this way the threshold setting could be based on the reflectivity and/or color of the paper. On the other hand, using the left margin of the document as the background for the CALIBRATION PATTERN implies that a certain portion of the margin will be unavailable for information content. This was not considered to be a problem since it is highly unlikely there will be a need to transmit a document having no margins. A more critical question, however, is just how much of the margin will be required to support the CALIBRATION PATTERN, or equivalently, how many lines will the ATC

require to properly select an optimum threshold level. This issue is addressed Chapter 5.

A. PERFORMANCE REQUIREMENTS

In the selection of a CALIBRATION PATTERN, certain criteria should be followed. First and foremost, the pattern should allow the ATC to select the optimum threshold level, that is, the level that produces the highest resolution in the output. Secondly, the pattern should allow the ATC to produce consistent results; that is, with all inputs constant, the ATC should generate the same threshold level again and again. Thirdly, the pattern characteristics should be invariant to light and/or paper characteristics. And finally, the pattern should be of the proper dimensions in order to fit in the margin of the document.

B. PATTERN COMPOSITION

The discussion thus far has been directed toward the fact that the CALIBRATION PATTERN would consist of a series of parallel lines, and it is easy to see why this would be a logical choice. At the very low spatial frequencies, a series of black lines separated by white spaces of equal width (called line-pairs) produces a square wave in the analog video signal. As the line-pairs become thinner, thus causing the spatial frequency to increase, the black and white analog levels migrate together, and the resulting analog video signal becomes very nearly sinusoidal and extremely predictable. The relationship, illustrated before in Figure 2.4, is re-oriented in Figure 3.1(A)

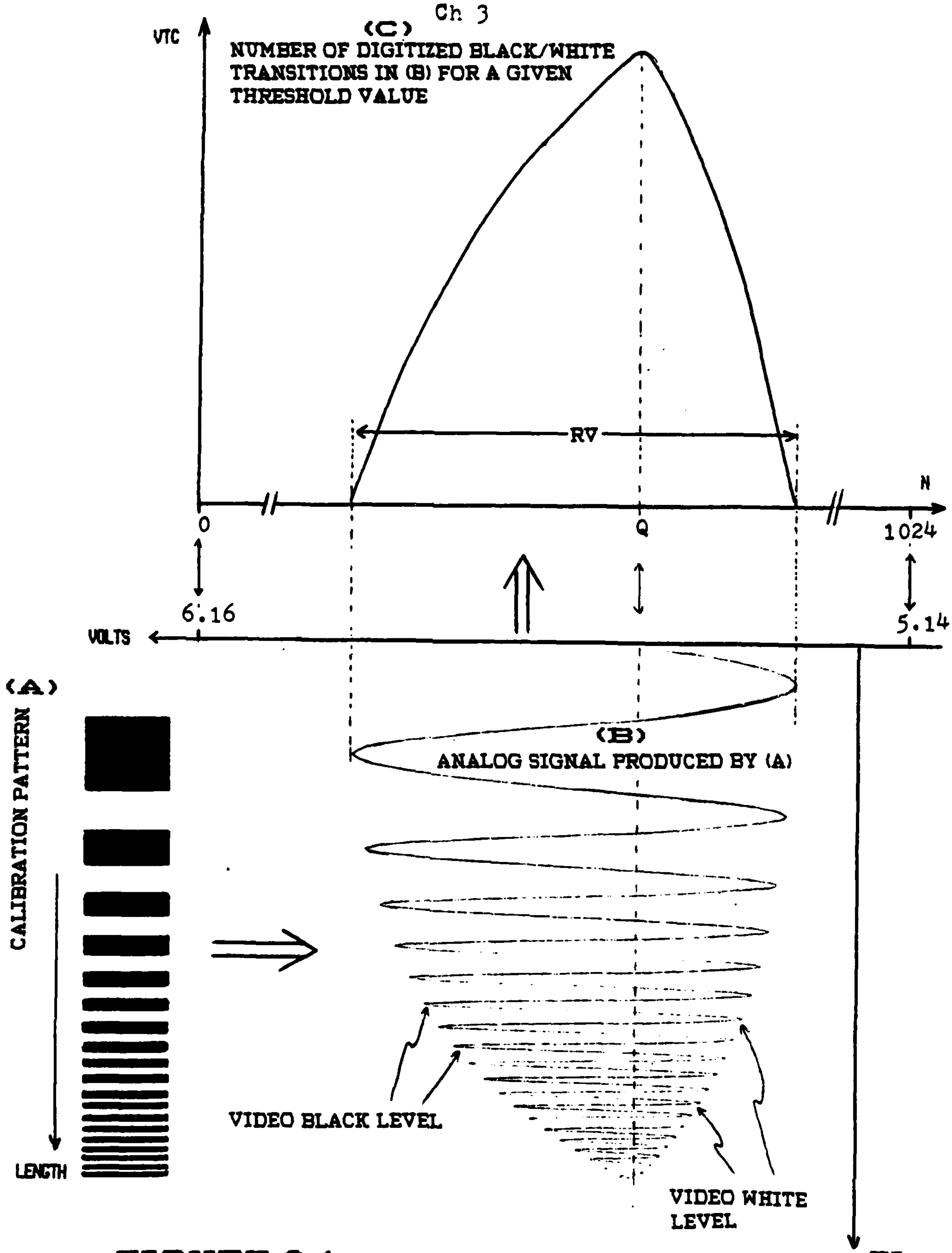


FIGURE 3.1 RELATION AMONG CALIBRATION PATTERN, ANALOG VIDEO SIGNAL, AND VTC-VERSUS-N CURVE

and (B). (1) So given that the CALIBRATION PATTERN will consist of line-pairs, the real question therefore is what spatial frequency or frequencies will be represented by the line-pairs. As mentioned in Chapter 2, the theoretical best choice would be a pattern that equally represented all spatial frequencies up to the CCD Nyquist rate of 100 line-pairs/inch. However it might also be possible that a pattern containing only the Nyquist frequency would be the best choice. It turns out that the very small pel swing generated by the Nyquist rate would be a significant disadvantage to the development of an efficient sampling algorithm. This point is covered in Chapter 5. The object of this phase of research was to ascertain the proper CALIBRATION PATTERN composition by direct evaluation of various candidate patterns. Unfortunately, within the scope of the project, there were relatively few sample patterns available for evaluation. Still much insight was gained with the patterns at hand, and a workable facsimile for a CALIBRATION PATTERN was obtained.

Another important question in CALIBRATION PATTERN composition is, in physical terms: How far along the left margin should the pattern extend? Or in other words, how much of one line of analog video does it take to successfully select the optimum threshold level? The answer, while not simple, can be illustrated fairly easily. Figure 3.2(A) shows the analog video

(1) Disregard Figure 3.1(C) for the present time.

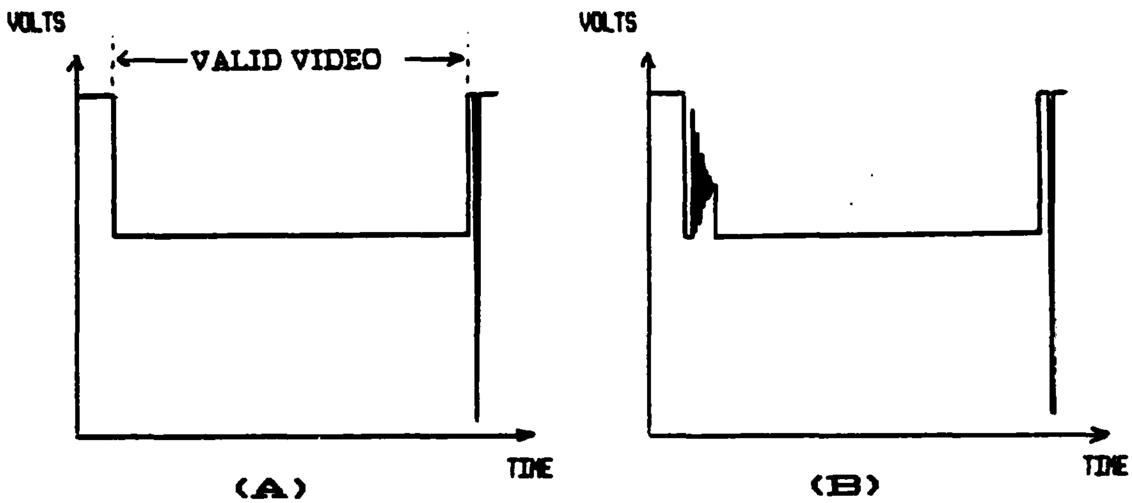


FIGURE 3.2 CALIBRATION PATTERN PLACEMENT EFFECTS ON THE ANALOG VIDEO SIGNAL

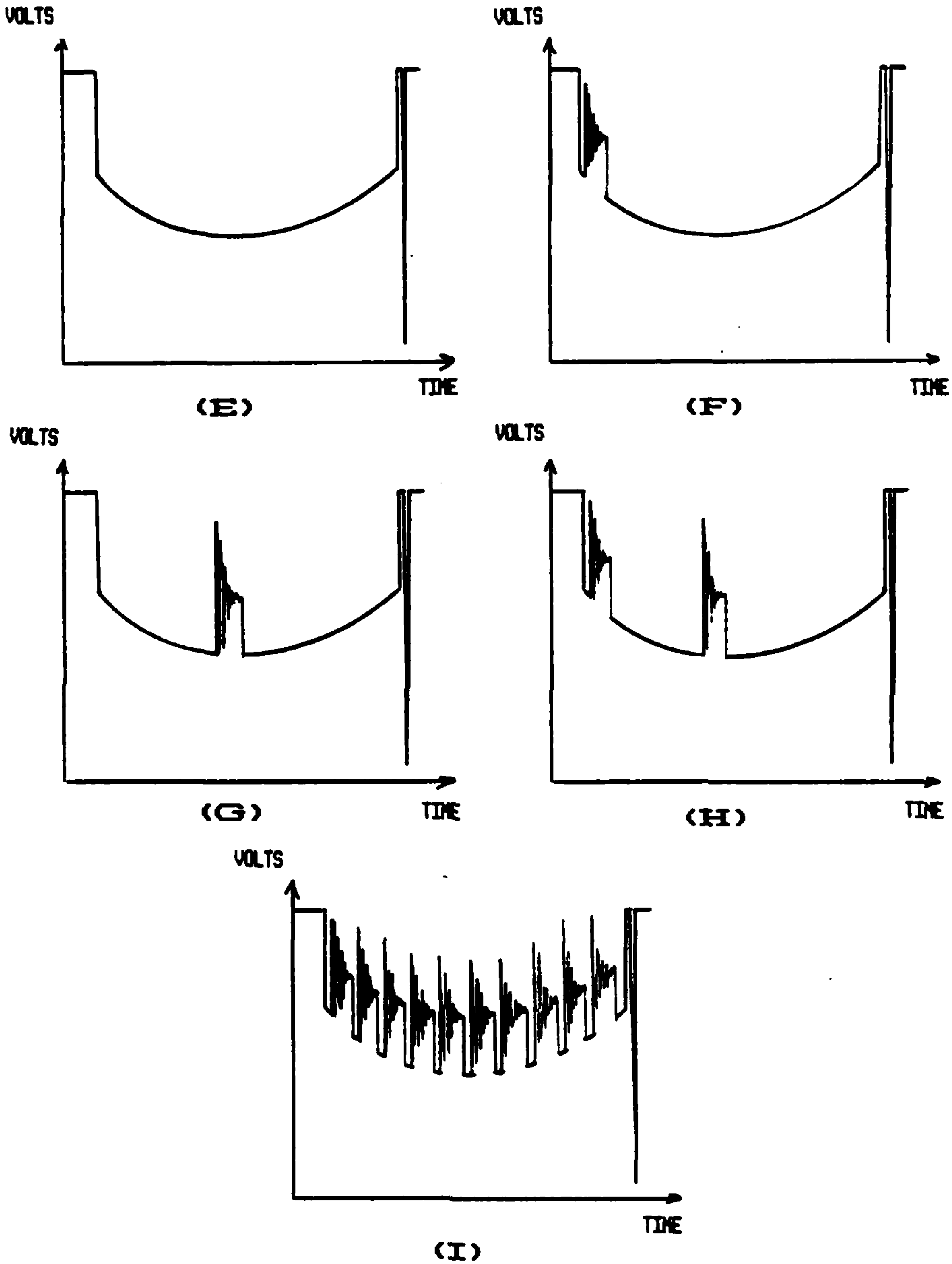


FIGURE 3.2 (CONT.)

signal resulting from scanning a blank white page with perfectly compensated illumination. Under these conditions, the CALIBRATION PATTERN that is superimposed on the white page would only need to be long enough to contain the necessary spatial frequencies, and could be located anywhere along the length of the margin. Figures 3.2(B), (C), and (D) show the analog signal that would result for pattern length of about an inch and placement in the bottom, middle, and top of the margin respectively. Now, for some reason, let us assume the illumination is not uniform over the length of the page, as illustrated in 3.2(E). The threshold level is now sensitive to pattern placement along the length of the margin as shown in 3.2(F) and (G). However, two patterns placed as in 3.2(H) would result in a threshold being chosen somewhere between the levels of 3.2(F) and (G). Realizing that this is indeed a compromise necessitated by less than optimum illumination, it is still a better choice than either extreme. Extrapolating to the limit, it would be necessary to use an entire line of video to get the best average over a line for non-uniform lighting conditions. This line corresponds to the entire left margin and should be filled with repeated CALIBRATION PATTERNs as in 3.2(I).

C. EVALUATION RESULTS

CALIBRATION PATTERN evaluation consisted of two stages: plotting the digital video transition count (VTC) versus threshold level value (N) for all possible threshold values; and running actual copies with the threshold value that yielded the

maximum video transition count (MTC). The experimental CALIBRATION PATTERNs (ECPs) evaluated were obtained from the IEEE Std 167A-1975 Facsimile Test Chart whose data are contained in Appendix A. To simplify documentation, the ECPs that were examined are labeled A through F in Figure 3.3. Referring to this figure, ECP A (IEEE Facsimile Test Pattern 9) consists of repetitions of 12 discrete spatial frequencies ranging from 30.5 to 203 line-pairs/inch. ECPs B, C, and D (IEEE Facsimile Test Patterns 5, 4, and 3) are single-frequency patterns containing 48, 25, and 5 line-pairs/inch respectively. ECP E (IEEE Facsimile Test Pattern 19) contains 0.01-inch lines spaced 0.10 inch apart. ECP F is a vertical strip of pseudo-random text taken from the IEEE Facsimile Test Chart and chosen so as to fall in the 50-to-100 line-pairs/inch region of Test Pattern 12. While none of the ECPs precisely satisfy the theoretical criterion of containing all spatial frequencies up to the Nyquist value, it can be predicted that ECP A will exhibit the best performance due to its controlled distribution of discrete spatial frequencies. ECP F was included in the testing to get an idea of the behavior of the VTC curve when scanning a relatively uncontrolled variety of spatial frequencies.

A general plot of a VTC-versus-N curve is illustrated in Figure 3.4. To fully appreciate the information presented on this and similar plots to follow, a few details deserve highlighting. Recall first that the x and y scales represent integers; each unit increase in N corresponds to a decrease of

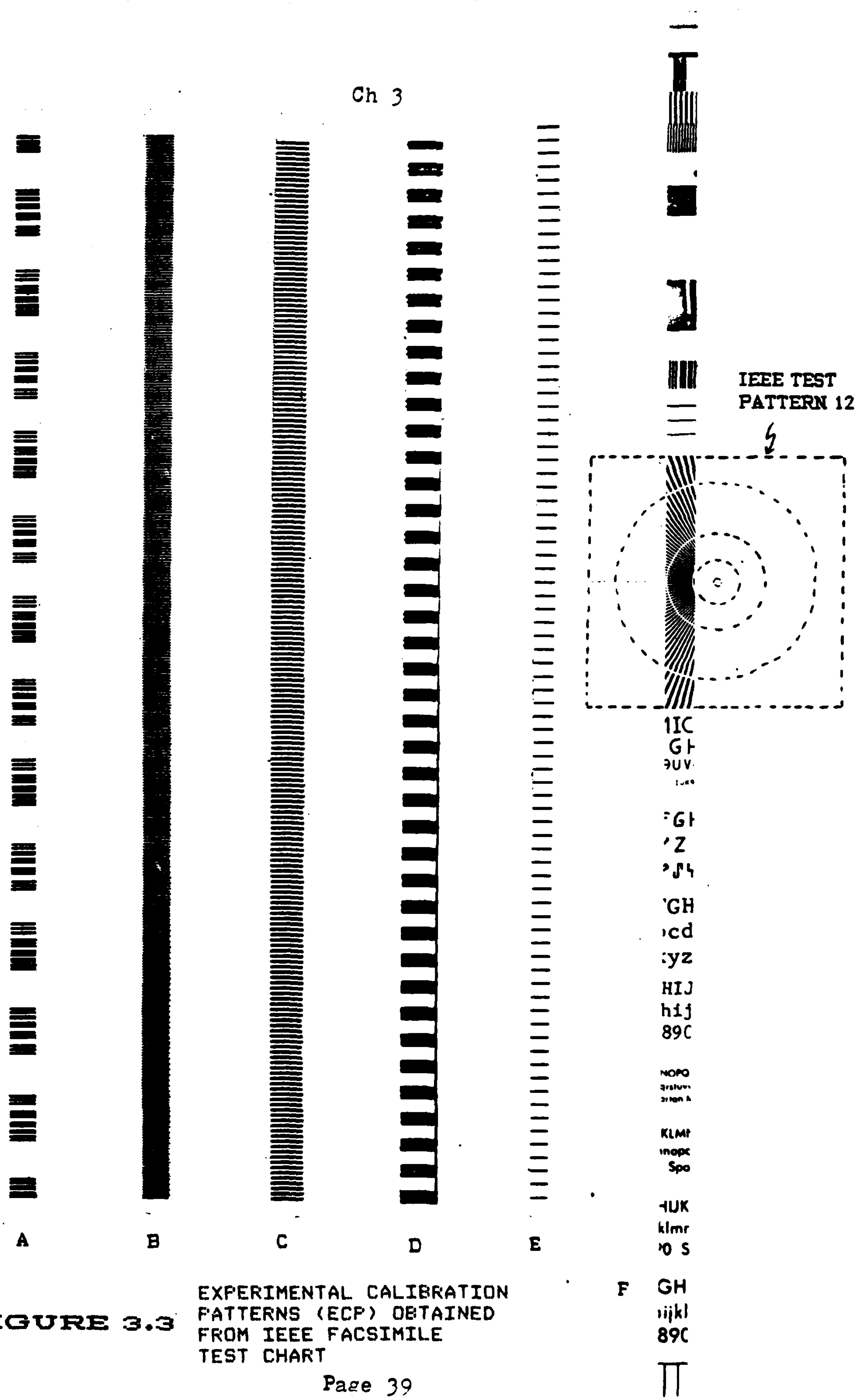


FIGURE 3.3 EXPERIMENTAL CALIBRATION PATTERNS (ECP) OBTAINED FROM IEEE FACSIMILE TEST CHART

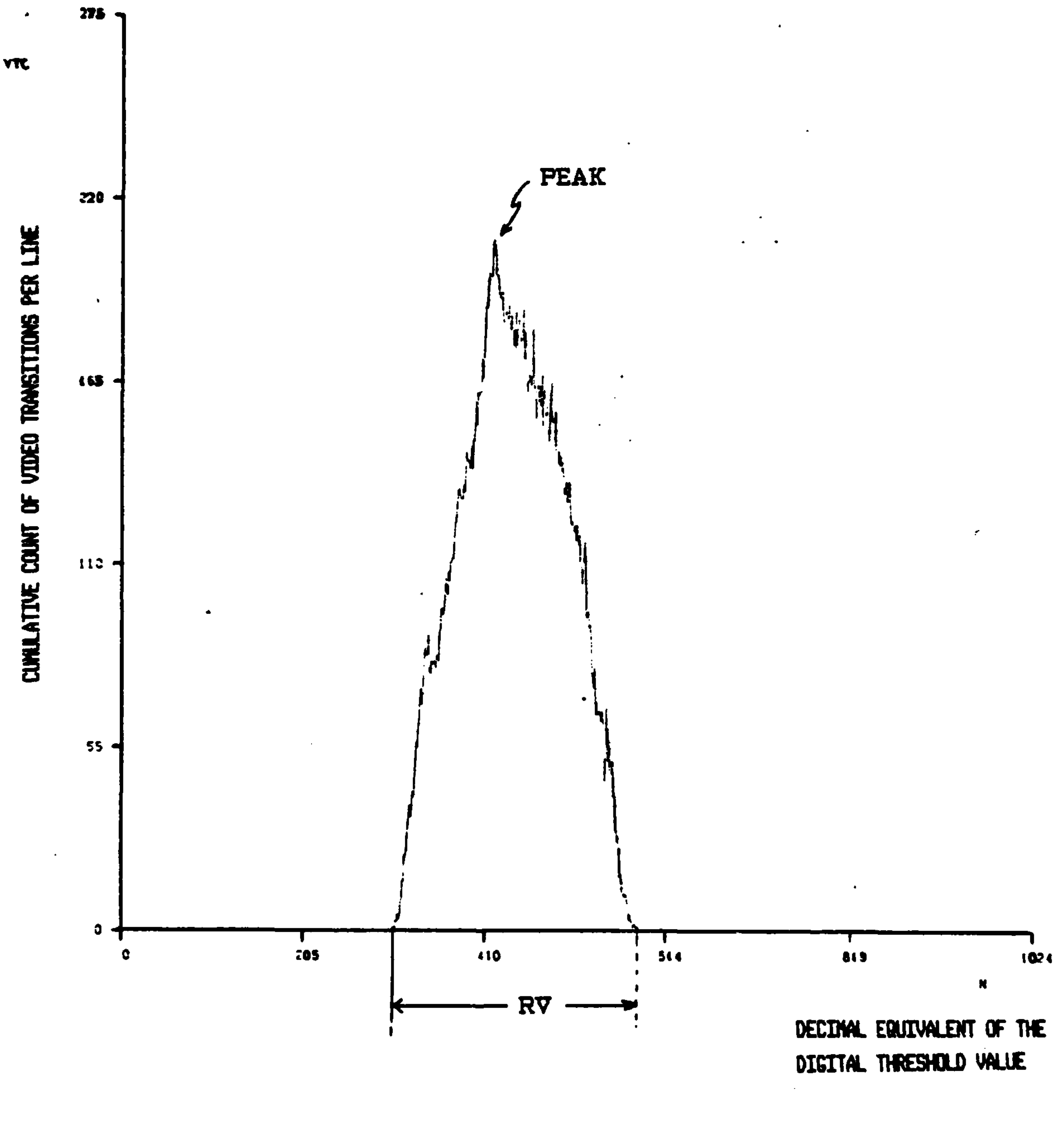


FIGURE 3.4 VTC CURVE PLOTTED OVER THE FULL RANGE OF N

one millivolt in the threshold level, and the dependent variable, VTC, is an accumulation of black/white transitions along one line of video for a given value of N. Although the full range of N is depicted, only a relatively small span contains pertinent information. Therefore, subsequent plots will constrain the N-axis to the span of significant VTC information. It should also become apparent that the span of N containing significant VTC information (subsequently called RV) is directly correlated to pel swing; larger pel swings will result in larger spans of RV, as illustrated by the relationship between parts (B) and (C) of Figure 3.1. This feature will be especially useful when comparing various plots. As for the vertical axis, VTC, it is emphasized that the absolute value, while interesting, is not nearly so significant as where along the horizontal axis the PEAK of VTC occurs. As an example, it is easy to see that ECP B in Figure 3.3 will have a much larger overall VTC than ECP D simply because it provides more black/white transitions per video line. This however does not mean that the peak of ECP B will be easier to detect. Since the idea is to work with digital information, the ATC will be equally capable of detecting a peak with a value of 800 or a peak with a value of 200. The absolute value of the peak is arbitrary. The important information is the value of N that causes the peak, because it is that value of N that the ATC should choose for its optimum threshold. One final property of these plots can best be described by referring to Figure 3.1. When N equals zero, the threshold level is at 6.16

volts, or well above the video signal. As N increases, the voltage threshold level decreases, eventually passing through the span of the analog video signal. On the basis that any portion of the analog video signal below the threshold level is decoded as white, and any portion of the analog signal above the threshold level is decoded as black, it can be seen that, when the threshold voltage lies between 6.16 volts and point Q, a portion of the video transitions to black are being lost. In other words, the digitized video signal contains less black information than it should. Conversely, when the threshold voltage is between point Q and 5.14 volts, the digitized video signal contains less white information than it should. So, when this information is applied to the VTC-versus-N plot in Figure 3.4, the values of N to the left of the VTC peak equate to thresholds that give lighter-than-optimum copy, and values of N to the right of the VTC peak equate to thresholds giving darker-than-optimum copy. This, of course, assumes that the VTC peak is indeed AT the optimum threshold N value. Figure 3.5 illustrates this point by showing scanner reproductions of IEEE Facsimile Test Pattern 12 for incremental increases of N. Note the lack of black information with the smaller values of N followed by lack of white information as N increases beyond optimum.

We are now in a position to intelligently analyze the VTC-versus-N plots for the various ECPs to see if an optimum threshold value is indeed pinpointed by the peak of the VTC

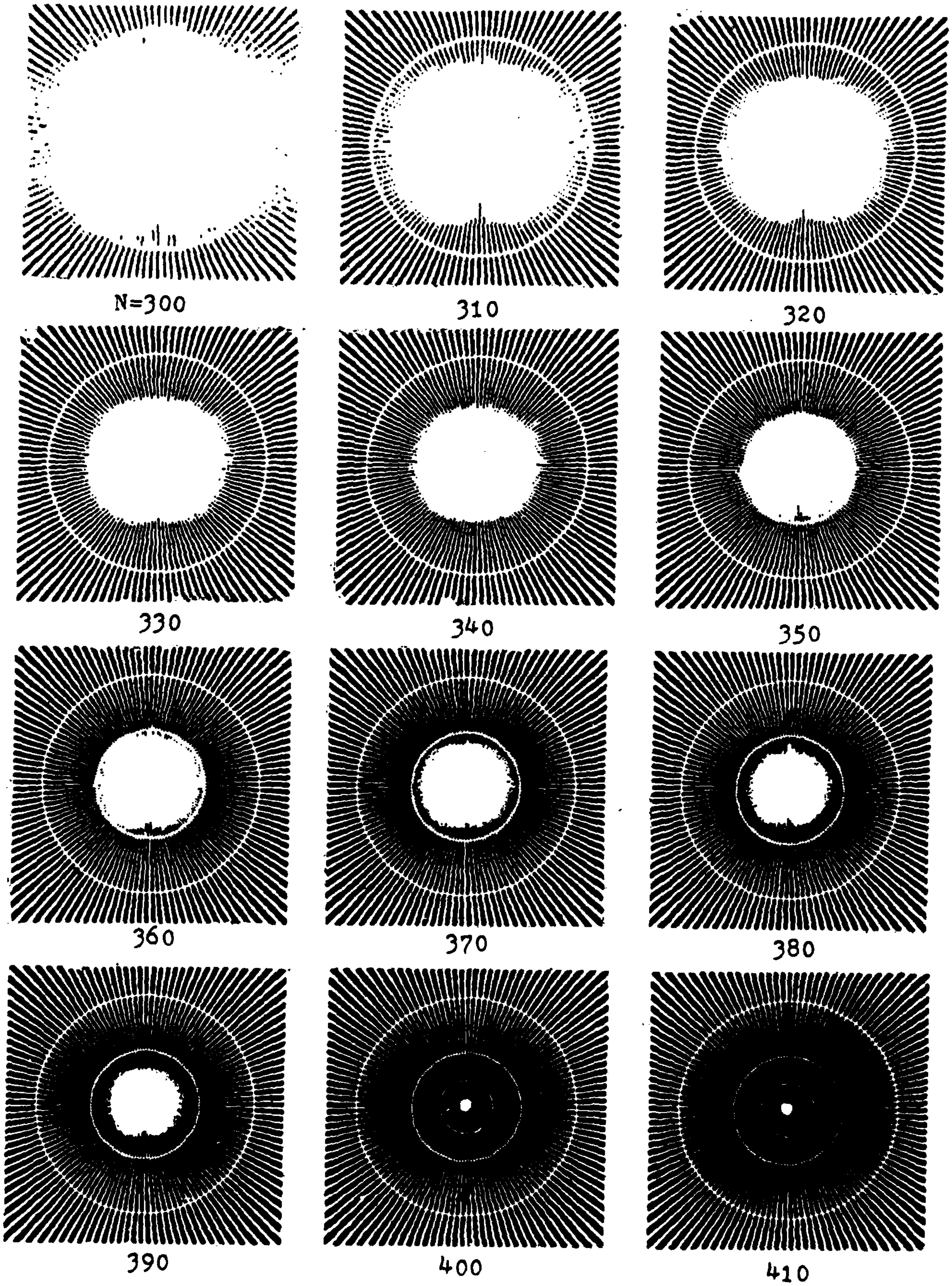


FIGURE 3.5 IEEE TEST PATTERN 12 SCANNED WITH INCREASING VALUES OF N WHICH CORRESPONDS TO DECREASING VALUES OF THRESHOLD VOLTAGE

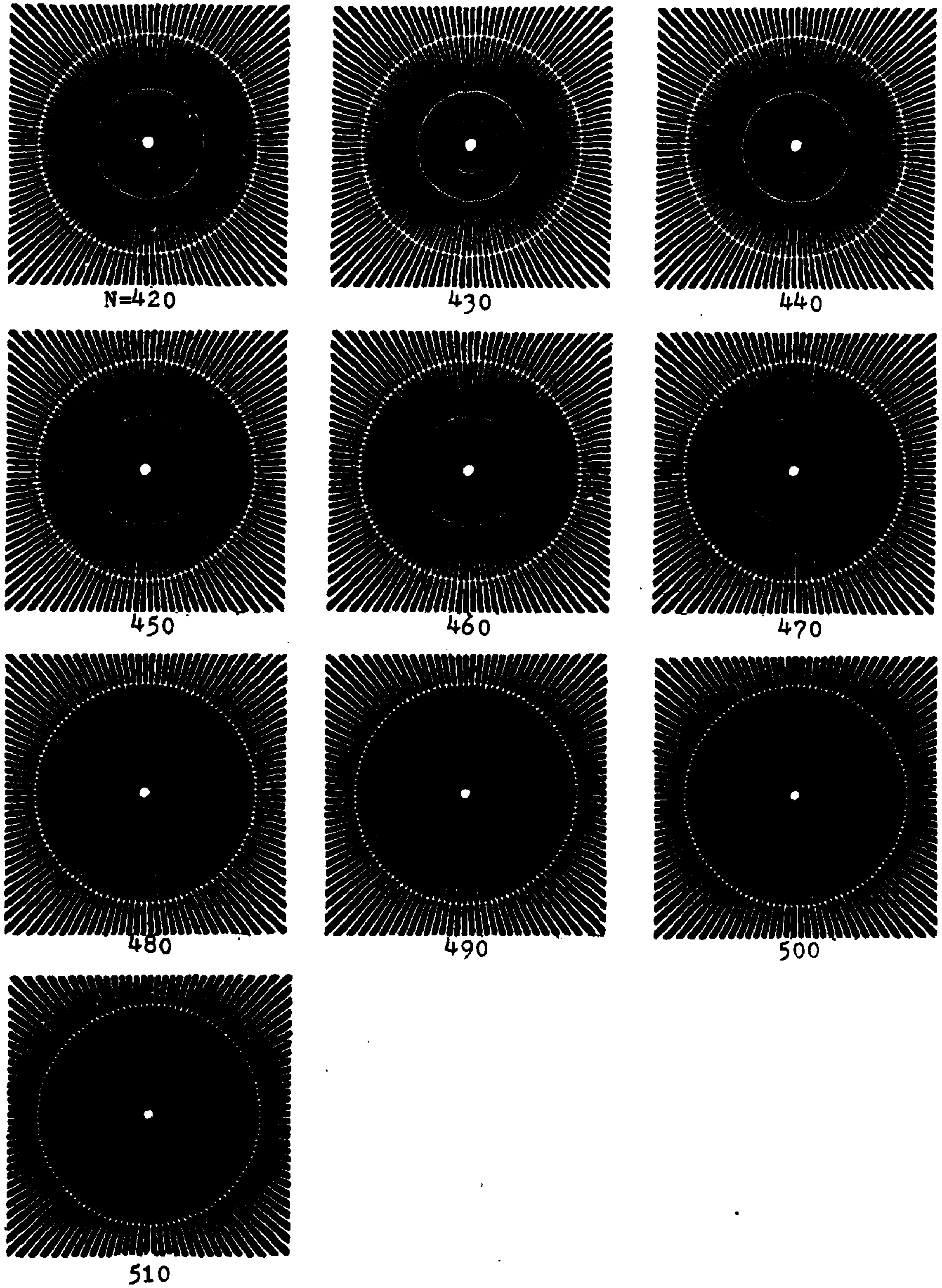


FIGURE 3.5 (CONT.)

curve. Figures 3.6 to 3.12 contain individual plots of the various ECPs. In Figure 3.6(A) ECP A was found to exhibit the desired characteristics required for the ATC. The peak of VTC was well defined and indeed occurred at a value of N that produced optimum hard copy as in Figure 3.6(B). Note that even in the copy in this report, (1) the capital letters in the 4-point type are legible.

When scanning a single discrete spatial frequency, the analog signal will be very nearly sinusoidal with constant amplitude. For this reason the number of black/white transitions will be constant in the span of significant video information. Accordingly, constant-frequency ECPs B, C, and D in Figure 3.3 produced predictable plateau-type curves. These curves are shown in Figures 3.7 to 3.9. The peaks for some undetermined reason occurred at either end of the plateau region, but intuitively it can be concluded that these peaks were not precipitated by valid video transitions. When hard copy was produced by thresholds based on these peaks, the results were as anticipated: either too light in the cases of ECPs B and C, or too dark in the case of ECP D. A comparison of the VTC plots of these three ECPs in Figure 3.10 provides an interesting manifestation of the

(1) Subsequent scanner outputs in this thesis will be xerox reproductions which fail to do complete justice to the actual scanner hard-copy output. Therefore in some cases, scanner output will only be described rather than included for viewing. Also the reader should be aware that the scanner system digitizes to only one binary level. Hence, gray tones in the IEEE Test Chart are not reproduced as such. The photograph, for example, (IEEE Test Pattern 15) is substantially degraded from the original.

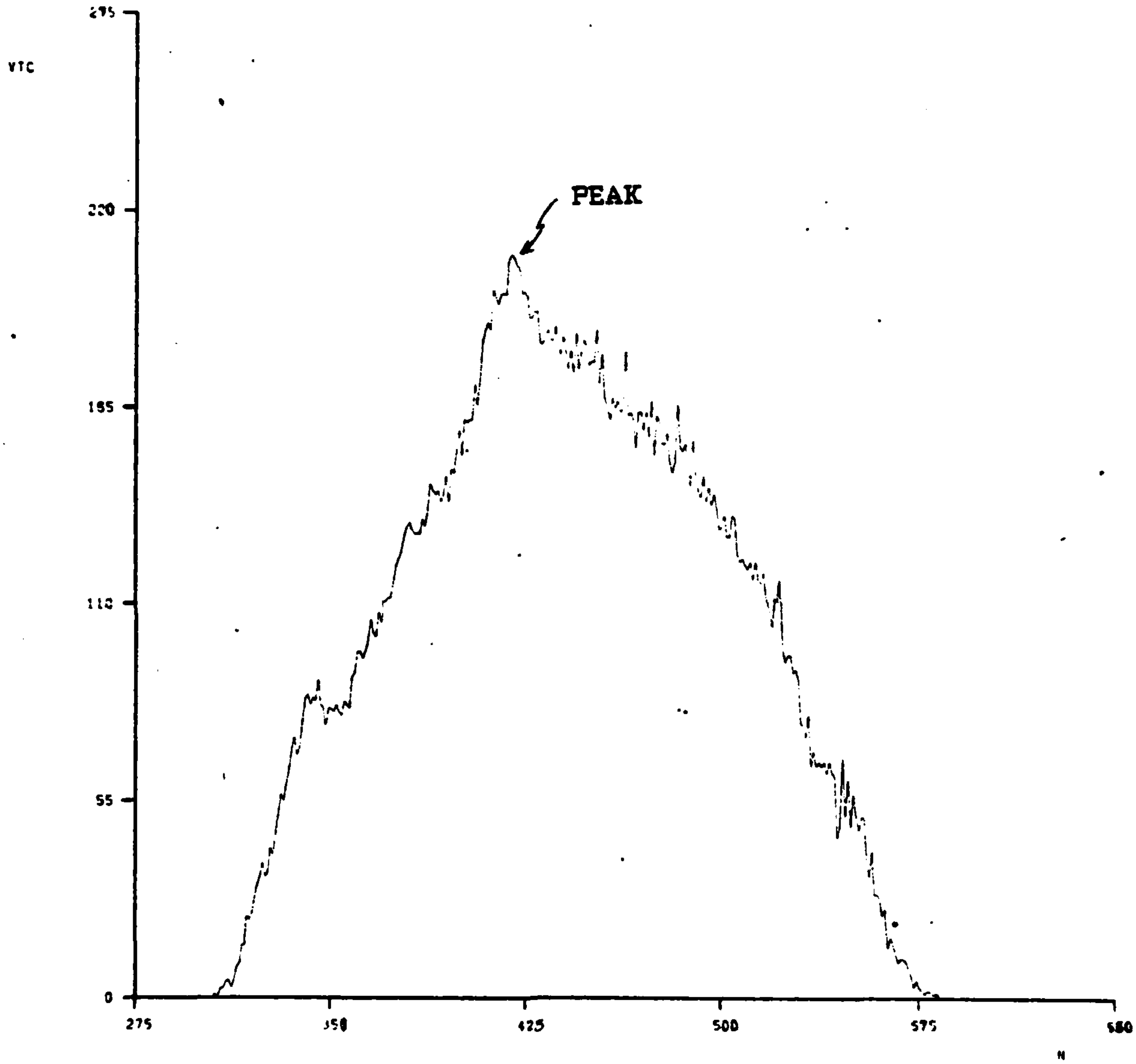


FIGURE 3.6(A) VTC-VERSUS-N CURVE FOR ECP A


NMA MICROFONT QJKLPYZ
ABCDEFGHIJKLMNOPQRS
ASA OCR-A
ABCDEFGHIJKLMNOPQRSTUV
WXYZabcdefghijklmnopqr
PICA
Elite
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890 Spartan Medium 8 pt
ABCDEFGHIJKLMNOPQRSTUVWXYZ
1234567890 Spartan Medium 10 pt
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890 Spartan Medium 12 pt
IEEE Std 167A-1975
FACSIMILE TEST CHART
65
120

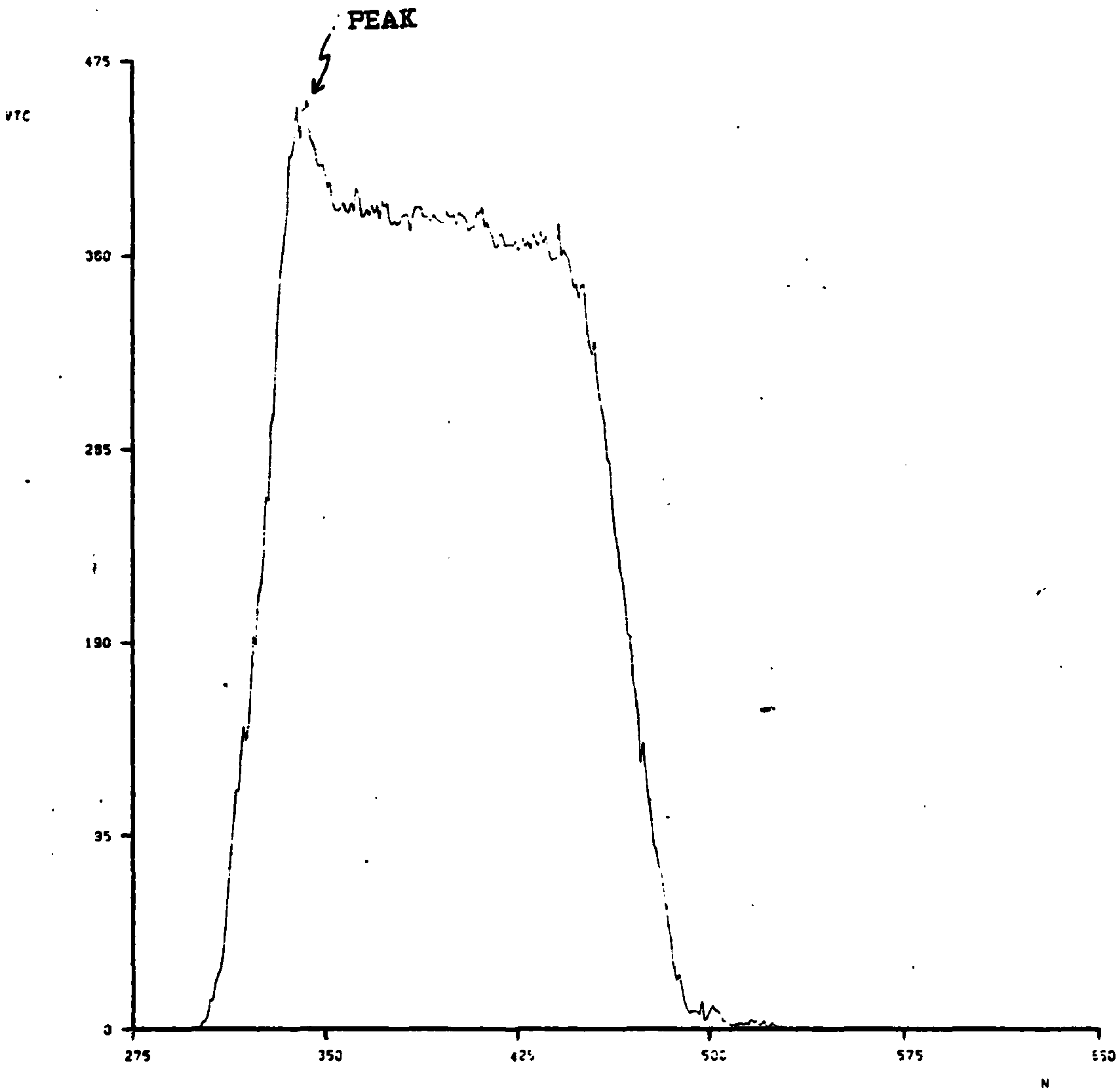


FIGURE 3.7 VTC-VERSUS-N CURVE FOR ECP B

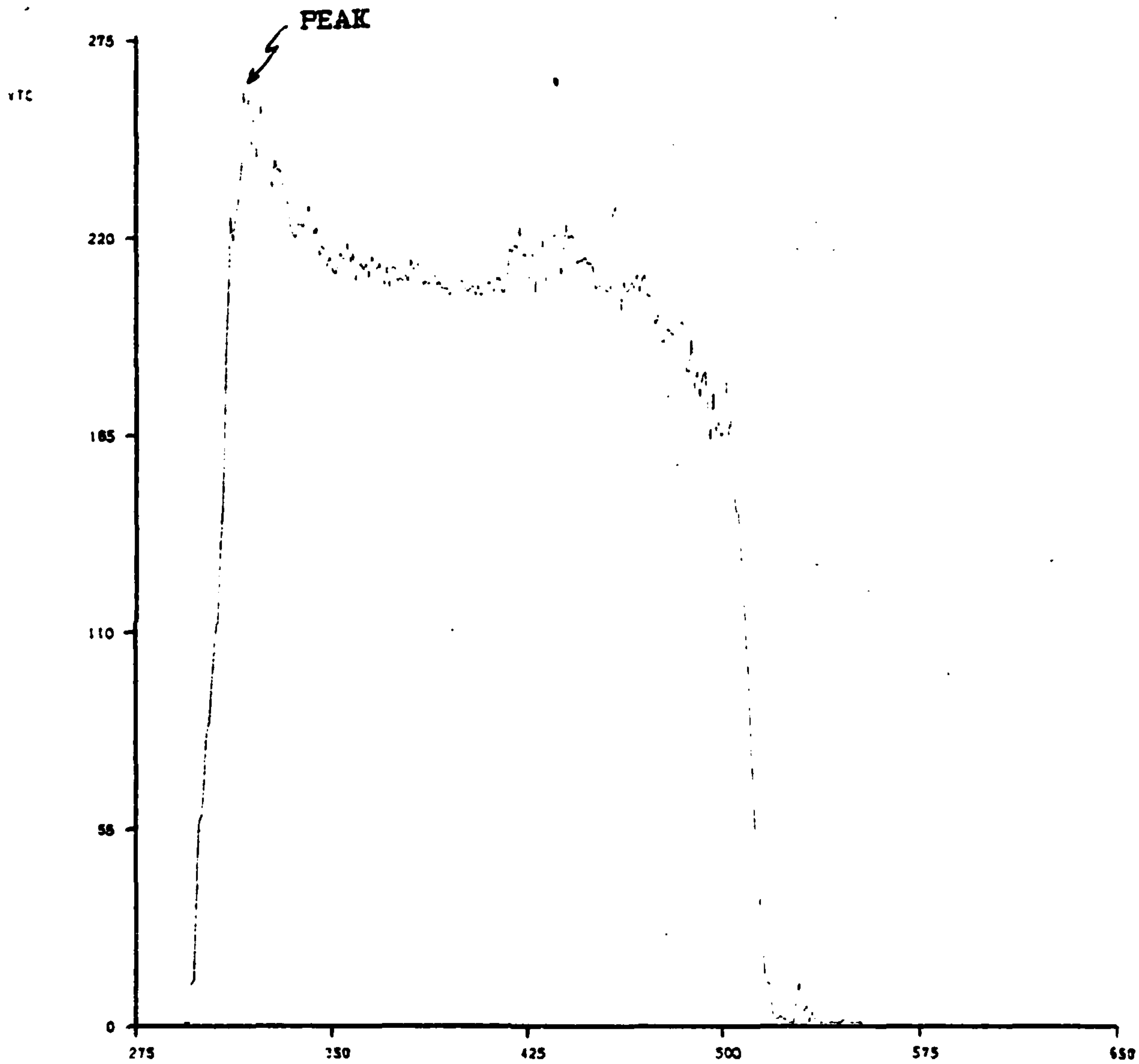


FIGURE 3.8 VTC-VERSUS-N CURVE FOR ECP C

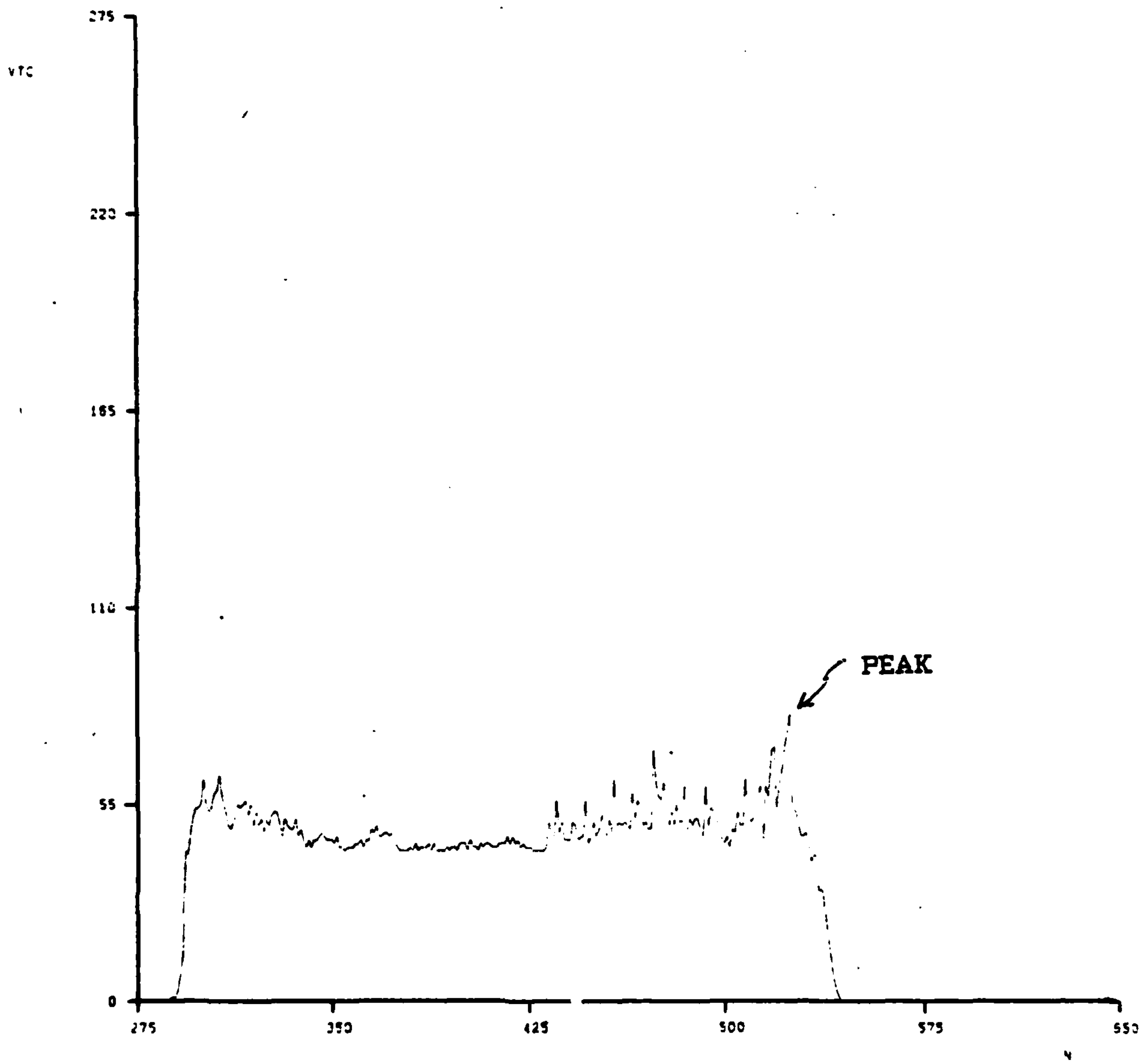


FIGURE 3.9 VTC-VERSUS-N CURVE FOR ECP D

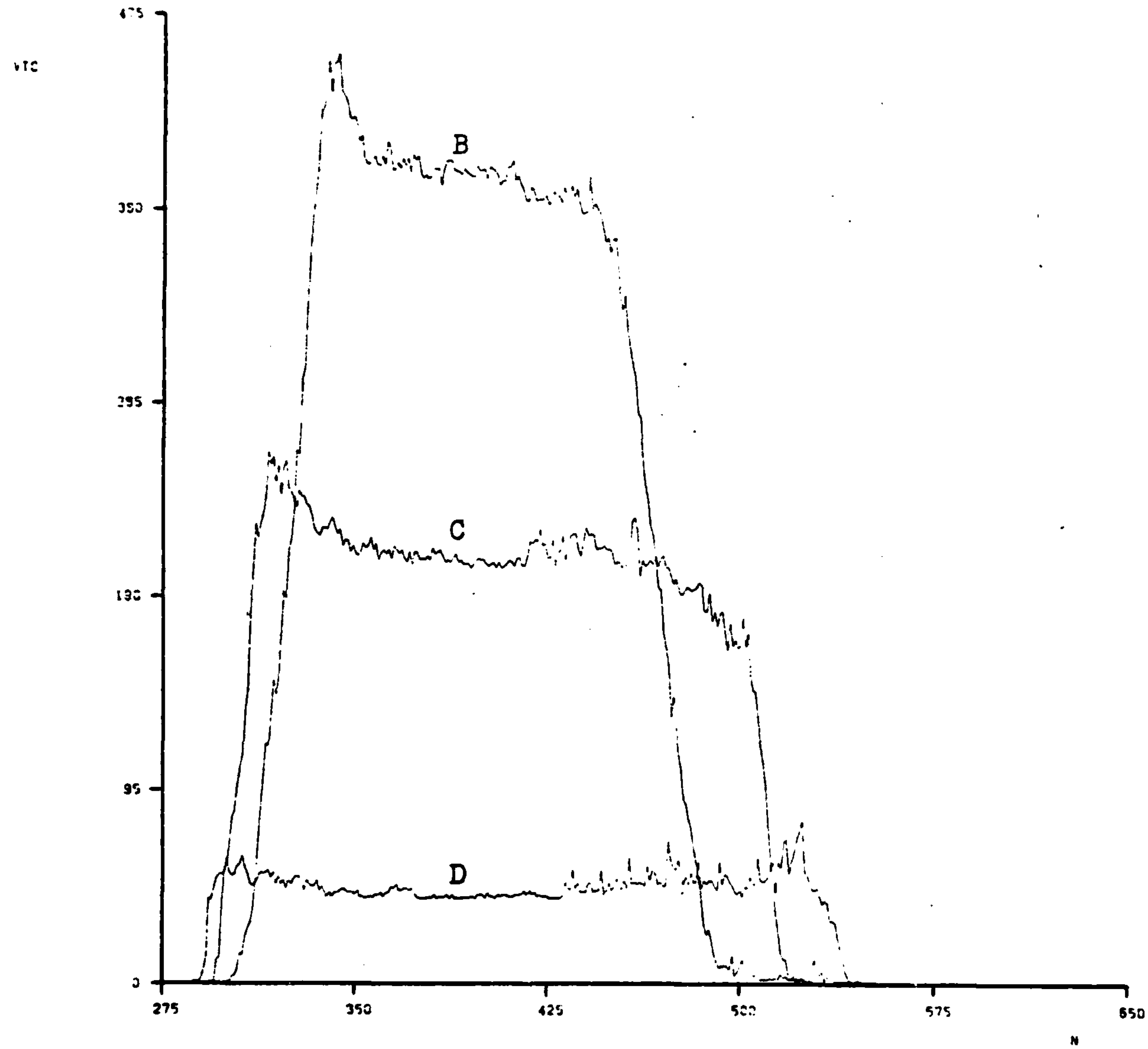


FIGURE 3.10 COMPARISON OF CONSTANT-FREQUENCY ECP PLOTS

reduction in RV spans with increasing spatial frequency due to smaller pel swings. And with increases in spatial frequency, the VTC curves naturally are higher due to more black/white transitions. The trend exhibited by these curves provides the probable conclusion that if an ECP were available containing the Nyquist frequency of 100 line-pairs/inch, it would most likely produce an impulse-like VTC curve centered around the value of N providing the optimum threshold level.

ECP E in Figure 3.3, due to its constant frequency nature, also yielded a plateau-shaped curve. See Figure 3.11. Its utility was no better than the other discrete-frequency ECPs. On the other hand, ECP F had a definable peak because of the variety of spatial frequencies present (Figure 3.12), but its usefulness was marginal since the actual peak information was occluded by the uncertainty in the data. Therefore, ECP A is obviously the best choice as a CALIBRATION PATTERN for the ATC. Figure 3.13 presents a comparison of all ECP plots as a convenience to the reader.

When the behavior of ECP A plots is analyzed with respect to other variables, further insight is gained to the robustness of its ability to select the optimum threshold value based on the VTC peak. For example, Figure 3.14 shows the behavior of the VTC curve with the loss of one fluorescent light. As expected, less light causes a smaller pel swing which is evidenced by comparing the spans of N in the two curves. Looking more closely, one can see that while the curves begin to rise at almost the same value

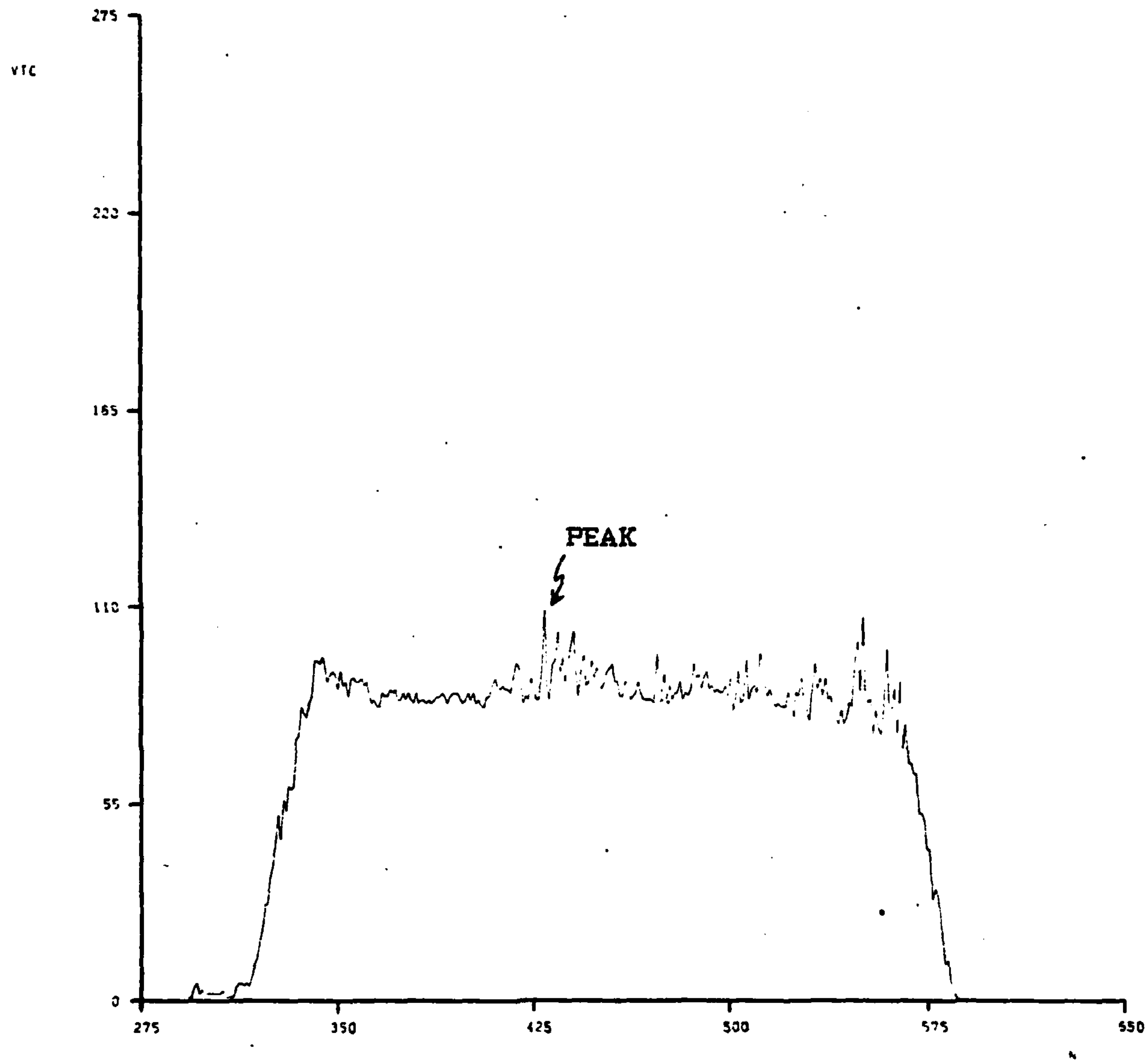


FIGURE 3.11 VTC-VERSUS-N CURVE FOR ECP E

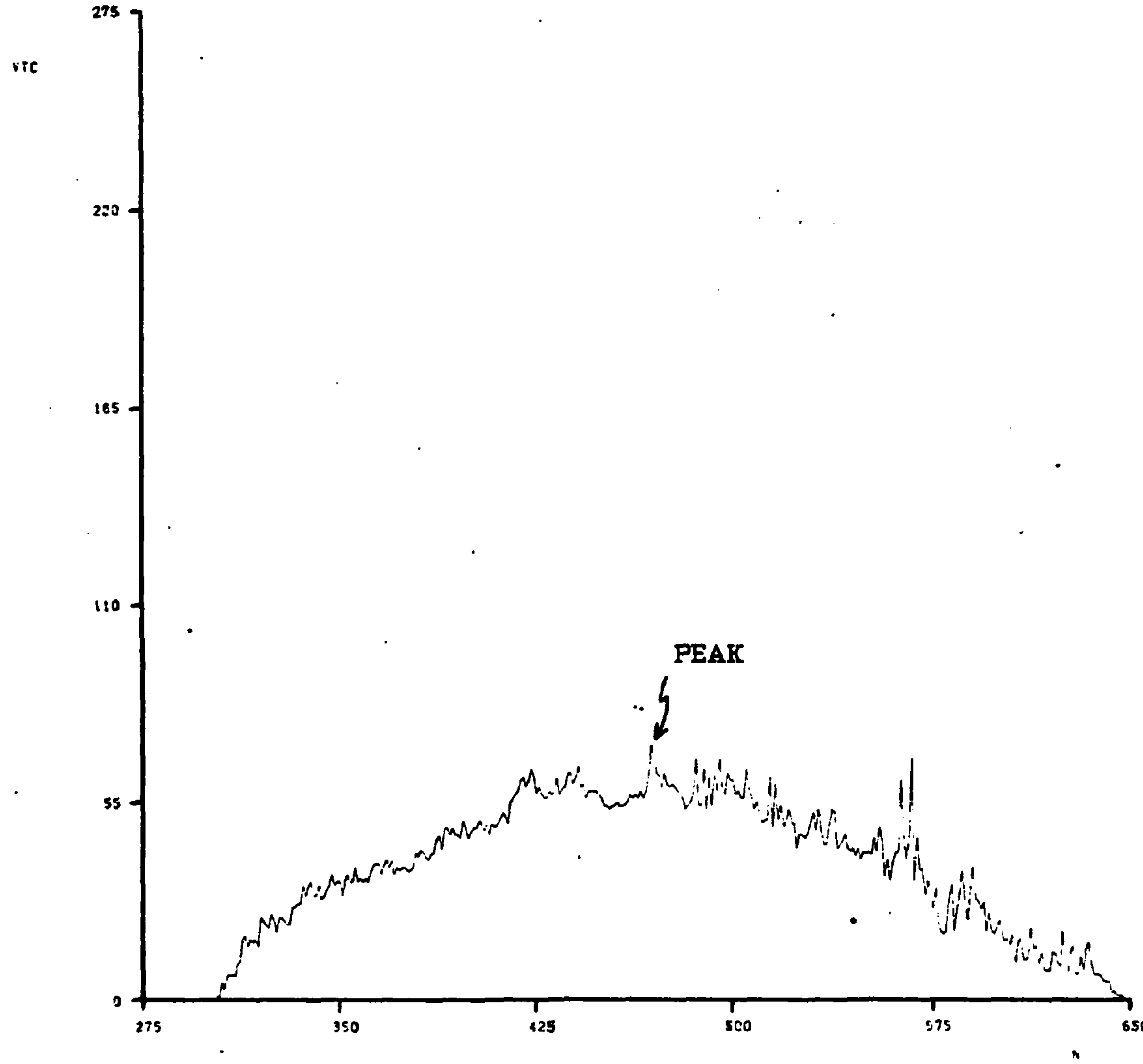


FIGURE 3.12 VTC-VERSUS-N CURVE FOR ECP F

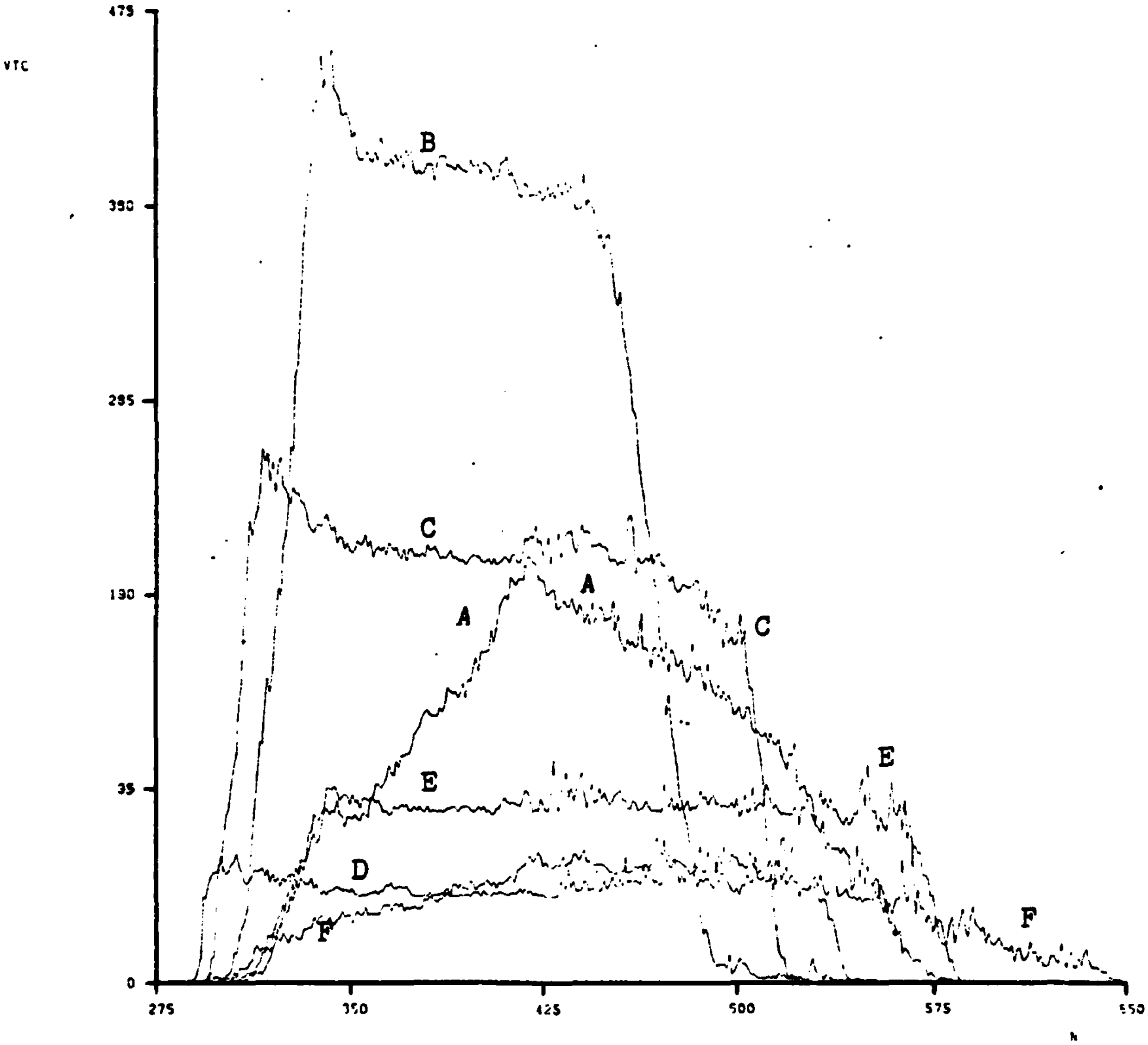


FIGURE 3.13 COMPARISON OF ECFs A THROUGH F

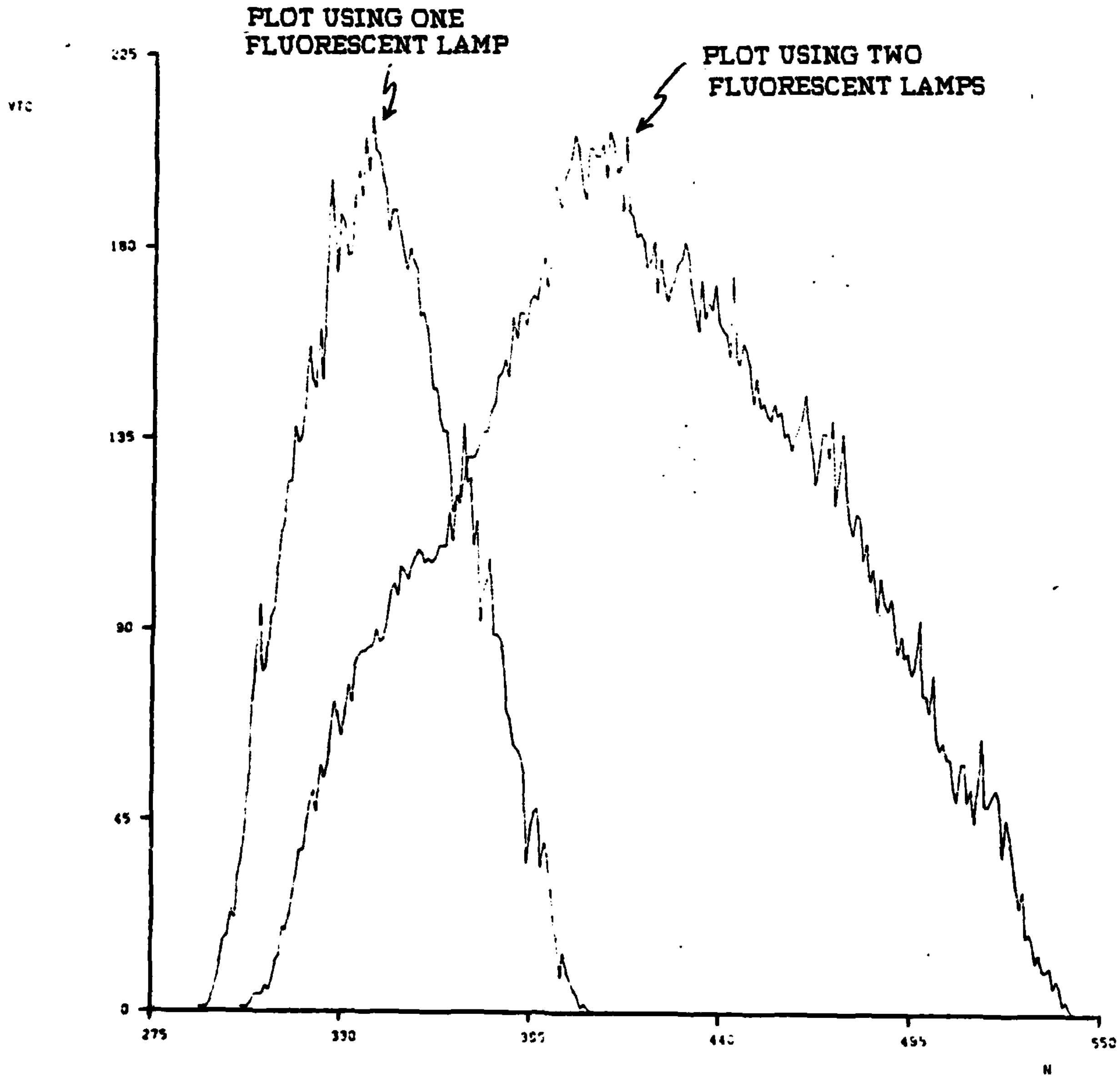


FIGURE 3.14 EFFECT OF ONE FLUORESCENT LAMP VERSUS TWO ON ECP A

of N on the left, they return to zero at much different N-values on the right. The interpretation is thus: In the analog video signal, different amounts of light cause small shifts in the black signal level but large shifts in the white signal level. It can also be seen that of the two curves, the curve resulting from one lamp has the steeper slopes on both sides. This means that an increase in light causes a more dramatic increase in pel swing at the lower spatial frequencies versus the higher spatial frequencies. But by far the most important result is that both curves display an obvious peak; one that will be chosen by the ATC algorithm. The threshold level defined by the two peaks were clearly optimum for the available light, as judged by the quality of hard copy output. (1)

Figure 3.15 illustrates similar effects with different colors of paper. Here the diminishing pel swing and increasing slopes are even more dramatic with the darker colors. As in Figure 3.14, there is a definite shift of the optimum threshold value, but the ATC design will inherently compensate for these shifts and continue to select the threshold providing the best resolution. (2) Figure 3.16 consists of plots using fluorescent lights with various spectral contents. The conclusion is that among the colors examined -- green, cool white, and warm white -- there was not a significant difference in performance, although

(1) Hard-copy samples resulting from single-lamp illumination are contained in Chapter 6.

(2) Scanner output of the IEEE Test Chart on red background is contained in Chapter 6.

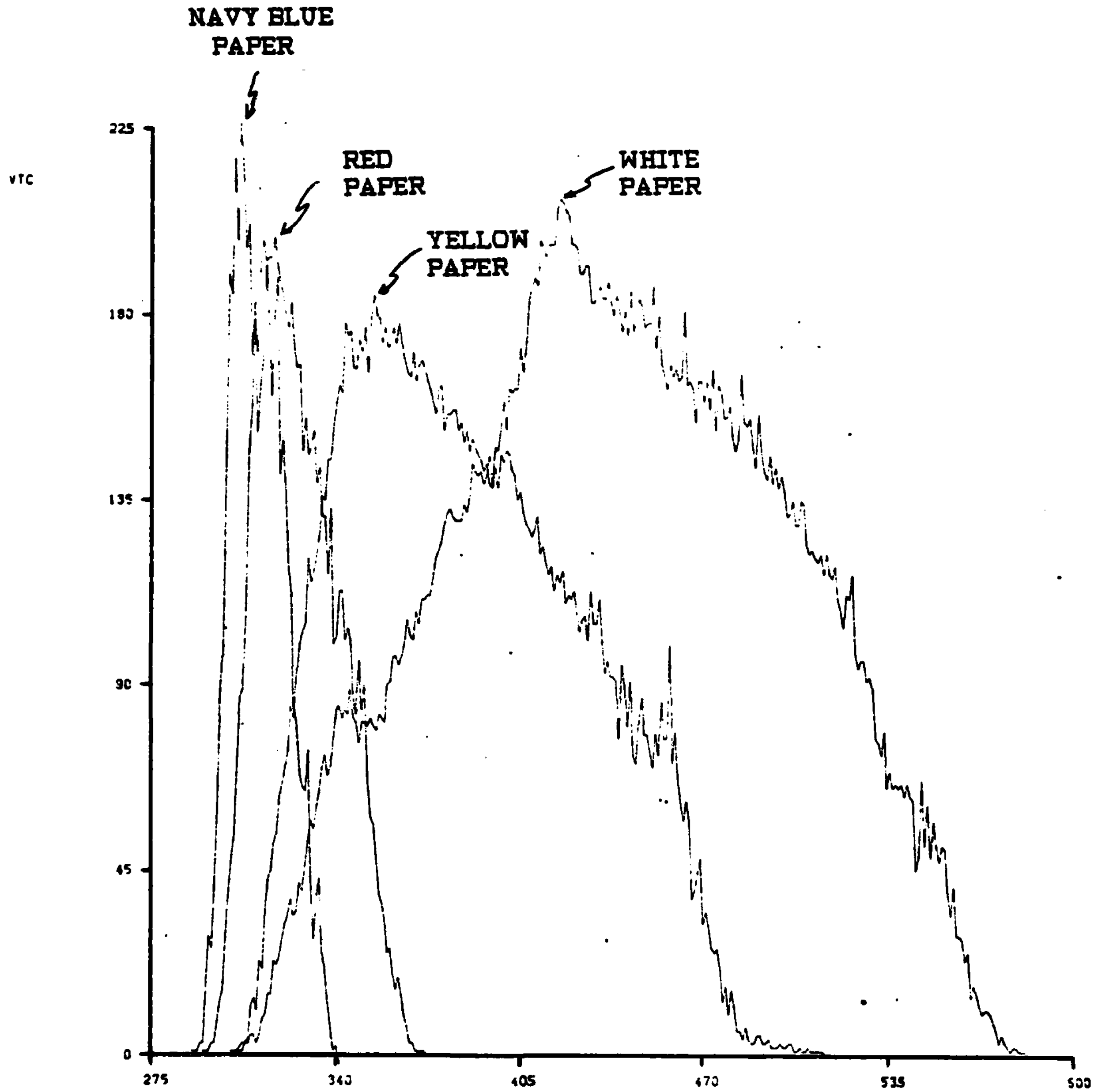


FIGURE 3.15 EFFECT OF DIFFERENT PAPER COLORS ON ECP A

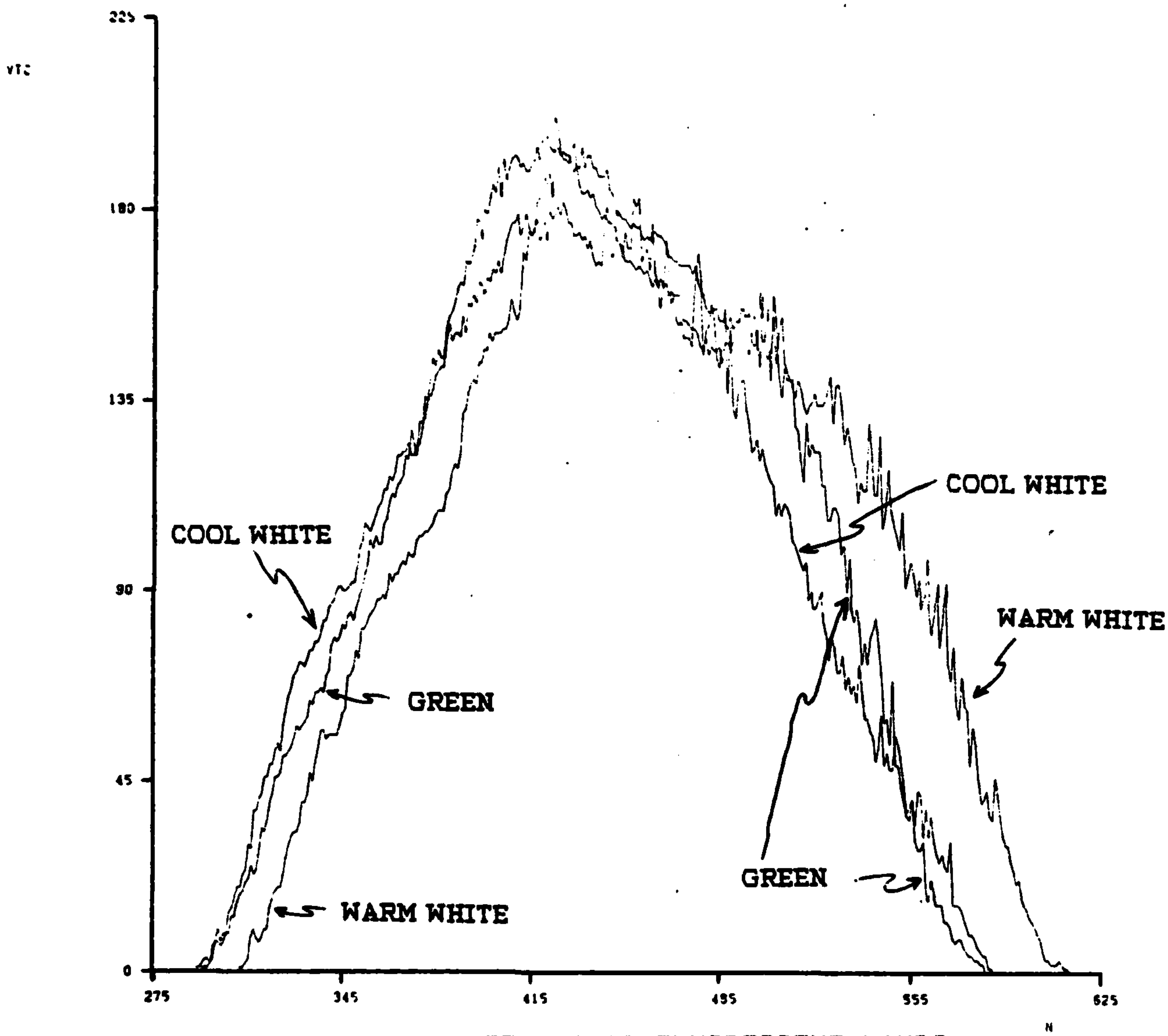


FIGURE 3.16 EFFECT OF FLUORESCENT LAMPS OF DIFFERENT SPECTRAL CONTENT ON ECP A

the warm white bulbs did appear to generate a slightly larger pel swing. On the other hand, Figure 3.17 demonstrates that fluorescent lights experience a certain amount of degradation over their lifetime. Once again the ATC will compensate for this effect. It should be noted that fluorescent lights deteriorate in a non-uniform manner over the length of the tube. Deposits on the inner walls near the filaments at either end cause excessive degradations in light emission at the ends, resulting in precisely the analog waveform illustrated in Figure 3.2(E).

As one final point, note that the curves contain a small degree of uncertainty rather than being smooth. It is hypothesized that the jitter is caused at least in part by the clocking noise in the scanner circuitry. Another cause could be power supply fluctuations producing minor deviations in the output of the circuitry generating the threshold voltage. The important conclusion is that while the general shape of the VTC curve is stable, individual plots will differ by some small amount as illustrated in Figure 3.18, which shows several runs taken under identical conditions. In this instance, extreme care was taken to insure all inputs remained constant, and yet there was still a small degree of inconsistency in the plots taken. The uncertainty that is present is by no means a barrier to the proper operation of the ATC, but the reader must be aware that the DEGREE of uncertainty in the VTC curve will have an effect on ATC performance especially with respect to the VTC sampling activities detailed in Chapter 5.

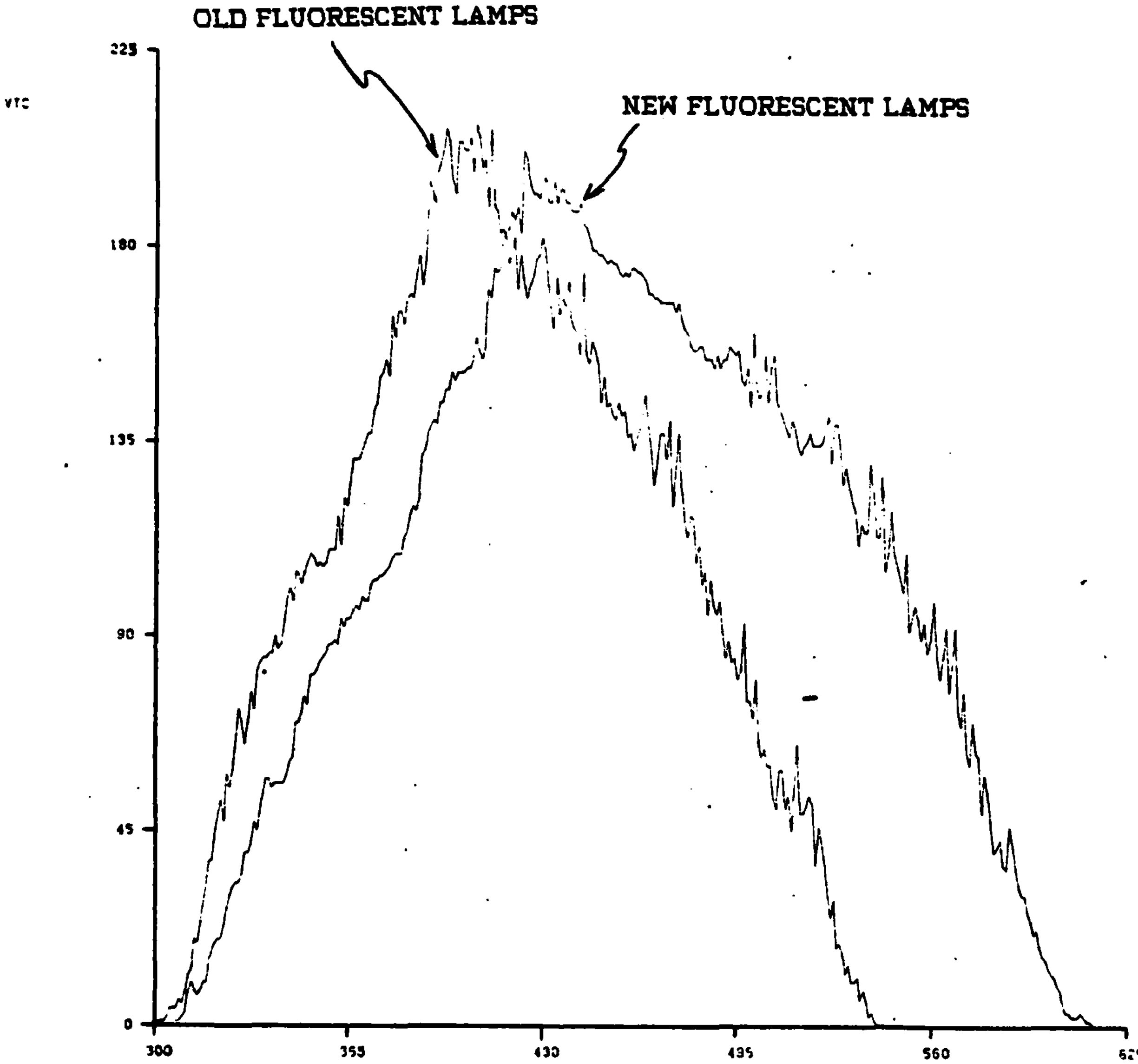


FIGURE 3.17 EFFECT OF OLD VERSUS NEW FLUORESCENT LAMPS ON ECP A

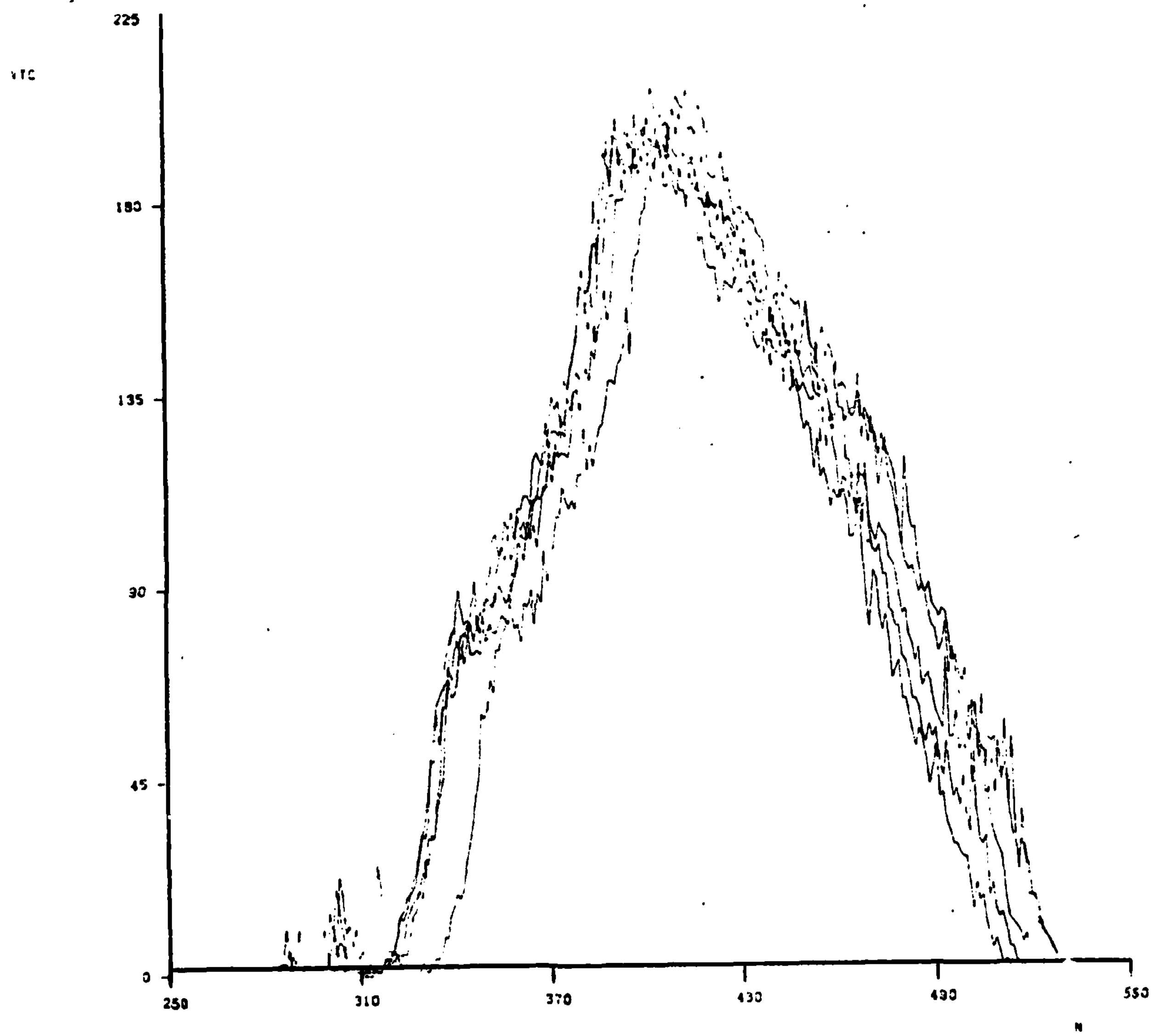


FIGURE 3.18: VTC FOR ECP A PLOTTED FIVE TIMES UNDER IDENTICAL CONDITIONS

CHAPTER 4

AUTOMATIC THRESHOLD CONTROL (ATC) DESIGN

A. ATC BLOCK DESCRIPTION

In terms of Chapter 3, the goal is now to design the necessary hardware to expeditiously pinpoint the threshold value, N, that generates the maximum number of black/white transitions. With the CALIBRATION PATTERN producing the desired analog signal, the THRESHOLD CONTROL UNIT (Figure 4.1) commands the THRESHOLD LEVEL GENERATOR to set a series of tentative threshold values for the A-to-D CONVERTER. The number of black/white transitions produced by each threshold value is summed by the VIDEO COUNTERS, and the sum, VTC, is correlated by the THRESHOLD CONTROL UNIT. Once all threshold values in the series have been tested, the THRESHOLD CONTROL UNIT locks in the threshold value that produced the maximum number of black/white transitions.

B. CHOICES FOR IMPLEMENTATION

Because of its availability and inclusion in the existing scanner, it was a logical decision to use the F8 microprocessor as the THRESHOLD CONTROL UNIT and to design a digital-to-analog circuit as the THRESHOLD LEVEL GENERATOR. The VIDEO COUNTERS provided a natural interface to the F8, but modifications in the video A-to-D section were required to upgrade the digital video signal to the quality required for accurate counting. The actual design details are covered in the next section.

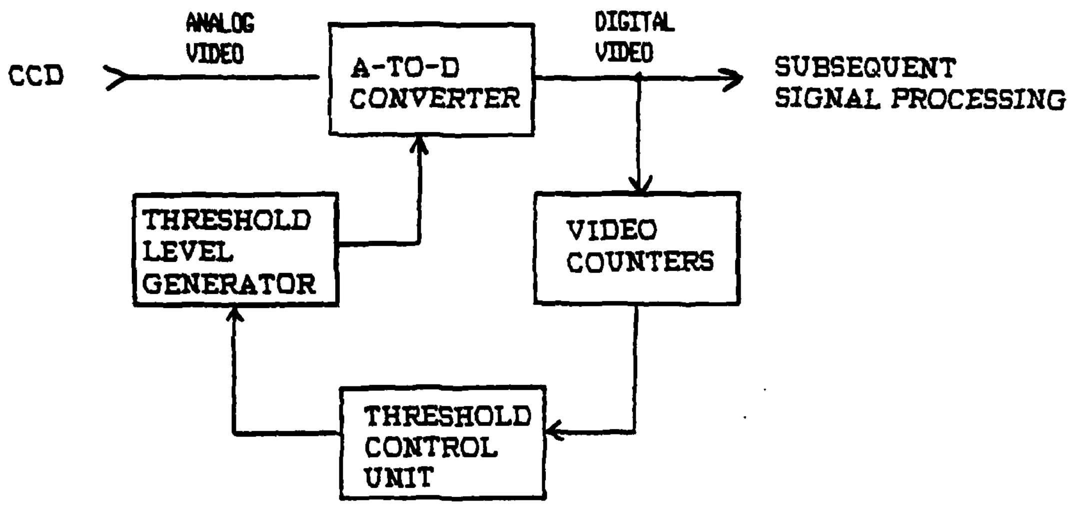


FIGURE 4.1 AUTOMATIC THRESHOLD CONTROL BLOCK DIAGRAM

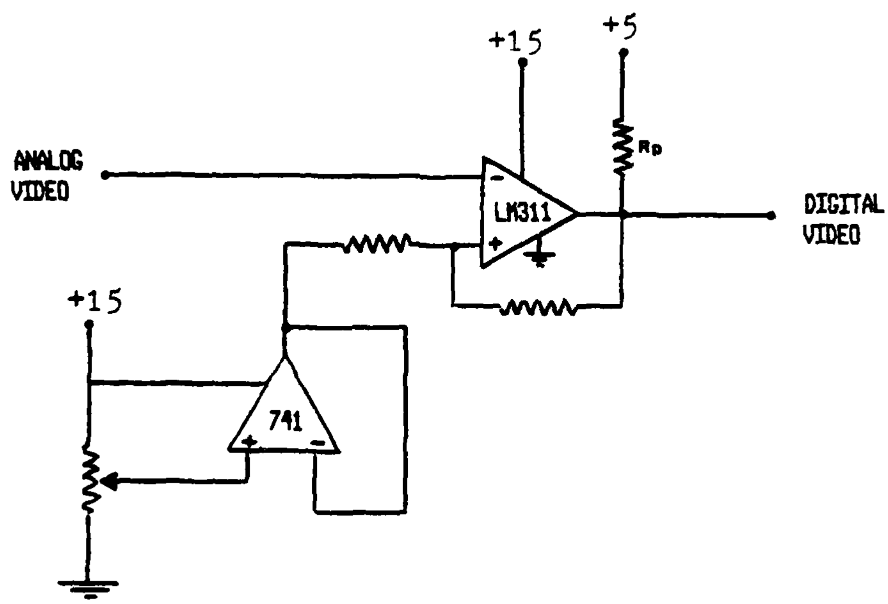


FIGURE 4.2 ORIGINAL VIDEO A-TO-D CONVERTER AND THRESHOLD LEVEL GENERATOR

C. CIRCUIT MODIFICATIONS

1. DIGITAL THRESHOLD LEVEL GENERATOR (TLG)

The existing scanner used a potentiometer buffered by a unity-gain 741 operational amplifier for manually setting the threshold level. See Figure 4.2. This circuit, which included an LM311 comparator as the A-to-D converter, was located on the TIMING & PROCESSING circuit board. It was removed entirely and is documented in Appendix E. A primary theme in the design of the new TLG was flexibility. That is, the circuit was constructed in such a way to allow for future alterations in voltage ranges and sensitivity for experimental purposes. The first consideration was the voltage range of the threshold level. In Chapter 2, it was found that the video information was within a span of 5.3 to 5.6 volts. Changes in the video signal were of the order of 10 to 300 millivolts. Therefore, the TLG had to be able to resolve millivolts in the 5.3 to 5.6-volt range. A 10-bit (1024-step) D-to-A converter was selected which would give a sensitivity of less than a millivolt/digital step over a range of one volt. Additional circuitry had to be added to the D-to-A converter to provide the necessary DC offset. Refer to Figure 4.3. The TLG consists of U1 through U6 with U4 providing the threshold output voltage, VO. U1 is an AD7533 D-to-A converter using an R-2R ladder network described in Appendix A, and U2 is a 741 operational amplifier used as a unity-gain buffer. The output of U2 is given as:

$$V2 = -Vref(N/1024) \qquad (1)$$

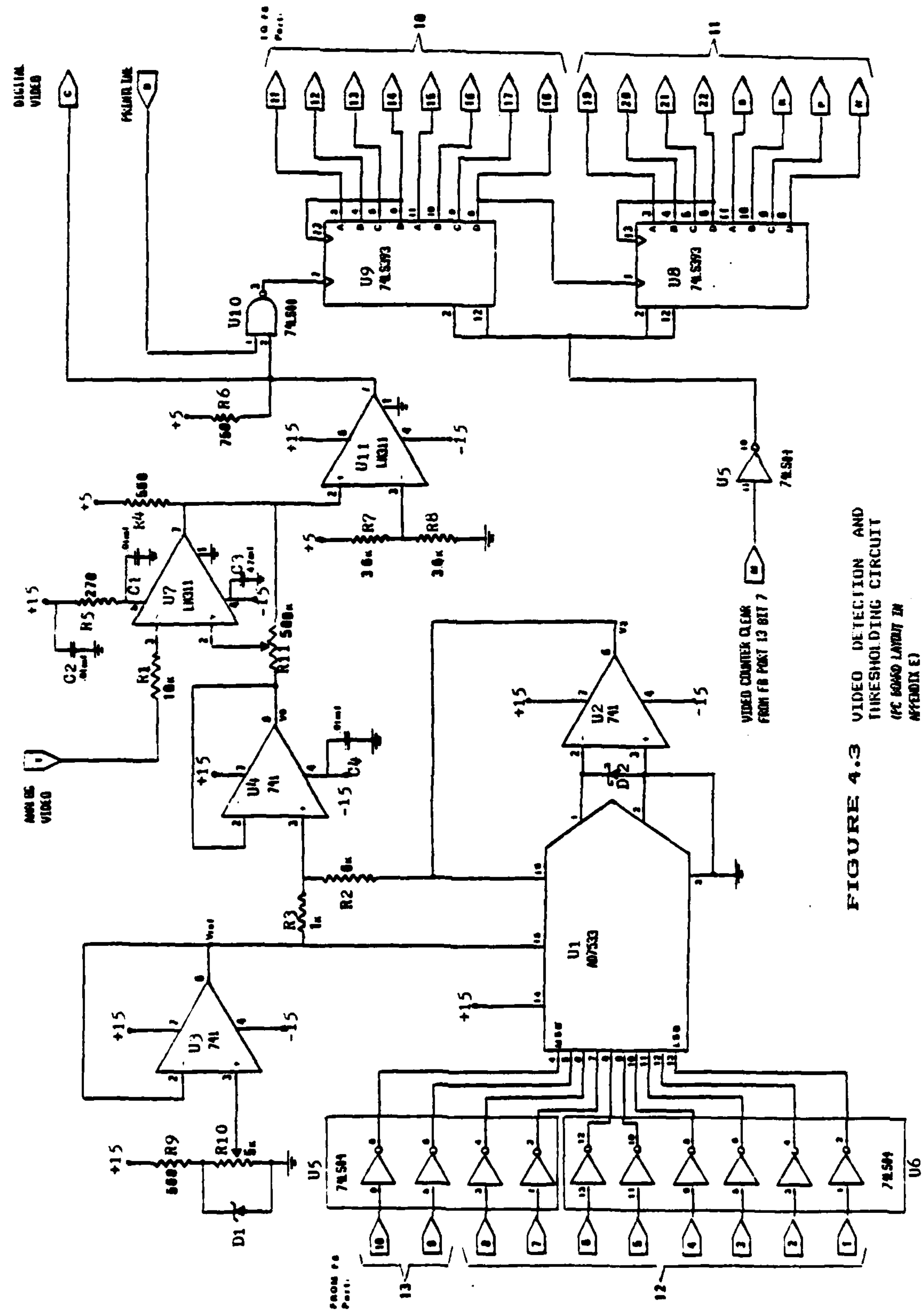


FIGURE 4.3 VIDEO DETECTION AND THRESHOLDING CIRCUIT (PC BOARD LAYOUT IN APPENDIX E)

where N is the decimal equivalent of the 10-bit binary input from the F8 to U1 through pins 4 through 13, and Vref is controlled by R10 and buffered with unity-gain op amp U3. Since op amp U4 is also a unity-gain buffer, V0 can be expressed as a function of the voltage division between Vref and V2:

$$V0 = \frac{(R3 \times V2) + (R2 \times Vref)}{(R2 + R3)} \qquad (2)$$

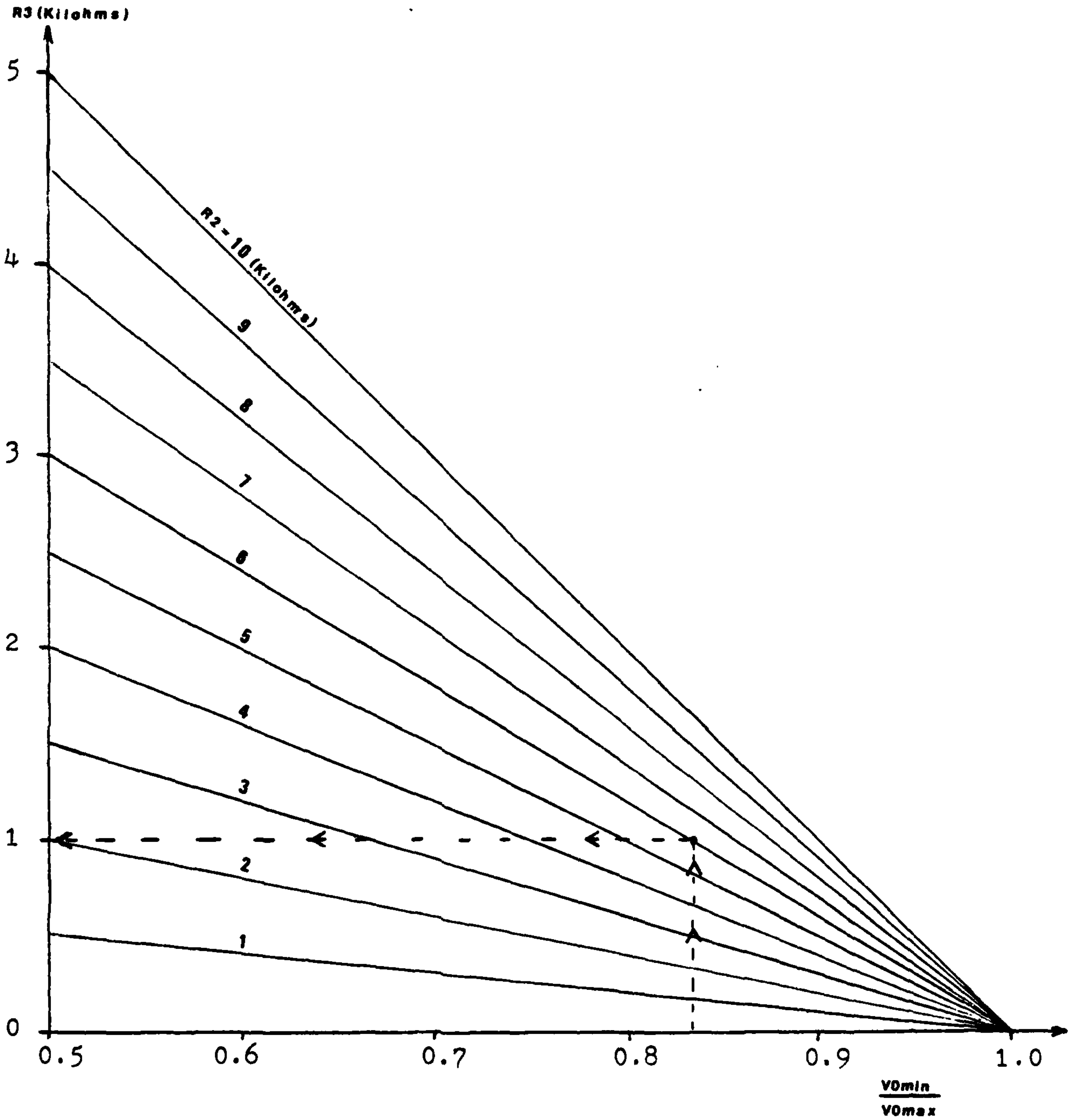
Eliminating V2, we have:

$$VO = Vref\left[\left(\frac{R2}{R2+R3}\right) - \left(\frac{R3}{R2+R3}\right)\left(\frac{D}{1024}\right)\right] \qquad (3)$$

Therefore, resistors R2, R3, and R10 control the width and placement of the range of the TLG. From Equation (3), a particular range (VOmin to VOmax) for the TLG can be established with the following procedure:

1. Determine values of V0min and V0max.
2. Arbitrarily select a nominal value for R2 in the range 1K to 10K ohms.
3. Calculate R3 for the R2-R3 voltage divider by:
   R3 = R2(1 - (VOmin/VOmax))
4. Calculate Vref by: Vref = (2 x VOmax) - VOmin
5. Set Vref by adjusting R10.

As an alternative, the graphs implementing Equation (3) in Figures 4.4 and 4.5 can be used as an aid to the calculations. The voltage range of the TLG used for this report was 5.14 to 6.16 volts giving a sensitivity of 1 millivolt/digital step. This choice is realistic and makes the results of the other



1. ENTER WITH VOLTAGE RATIO $\frac{VO_{min}}{VO_{max}}$
2. TRAVEL VERTICALLY TO DESIRED R2
3. TRAVEL LEFT TO READ VALUE OF R3

FIGURE 4.4 GRAPH FOR CALCULATING R3 OF TLG

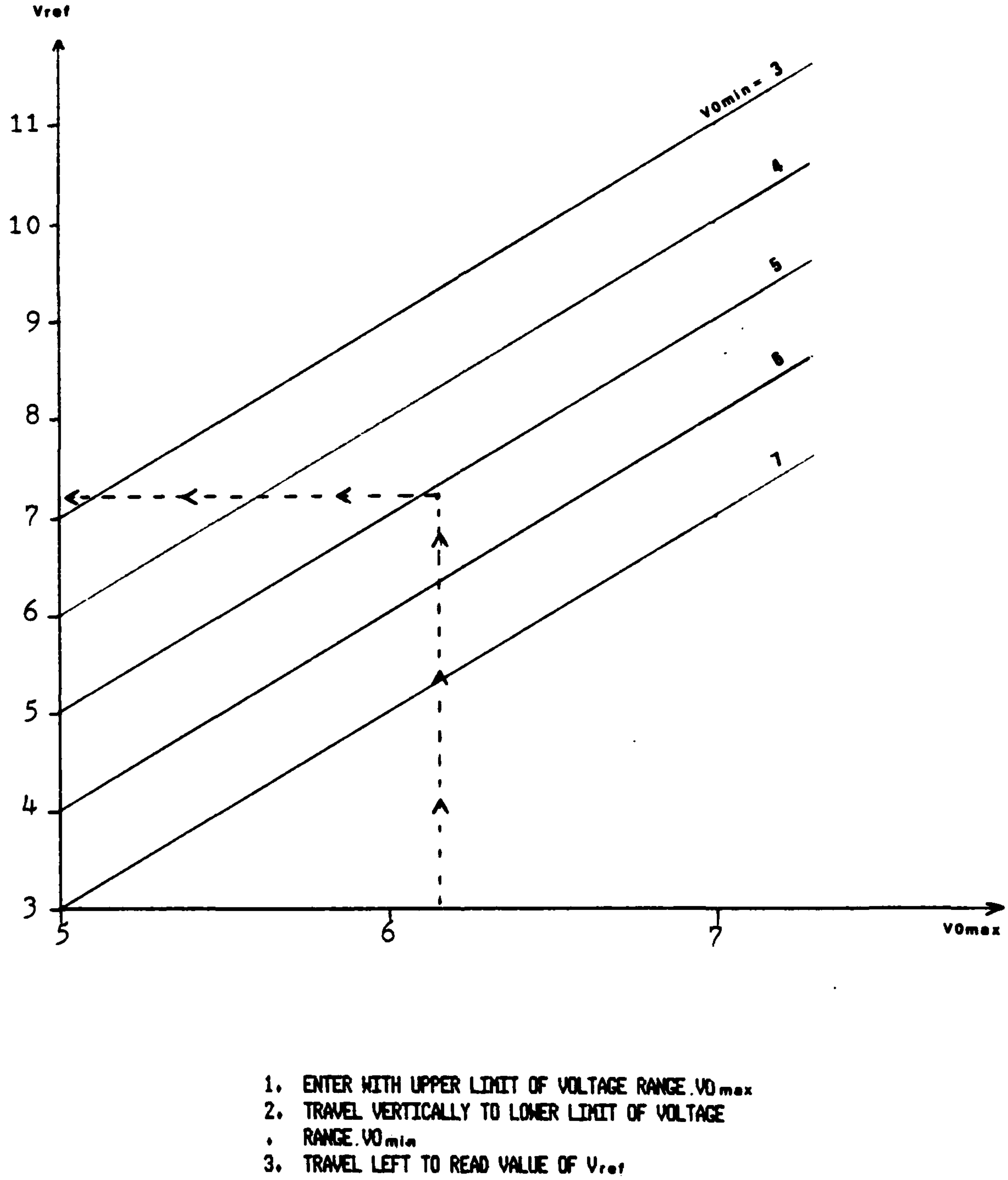


FIGURE 4.5 GRAPH FOR CALCULATING V_{ref} OF TLG

chapters particularly simple to interpret.

2. VIDEO A-TO-D DESIGN

Referring again to the scanner's original video A-to-D circuit in Figure 4.2, the response of this circuit to the highest spatial frequencies was found to be rather slow (3.03 microseconds) due to the size of the pull-up resistor, Rp. While this was adequate for the existing design and in fact helped prevent clock noise feed-through, it was found that the performance was inadequate as a clocking input to the VIDEO COUNTERS. Therefore in the re-design of the video A-to-D circuit, Rp was changed to 560 Ohms giving a rise time of 332 nanoseconds. This allowed the circuit to more faithfully digitize the spatial frequencies up to the Nyquist rate. This feature was essential so the VIDEO COUNTERS could record the black/white transitions of all the spatial frequencies. Unfortunately with the smaller Rp, unwanted clock noise was now passing through the one-stage comparator circuit, which would have been disastrous for the VIDEO COUNTERS. Therefore a second LM311 with a constant threshold of 2.5 volts was cascaded with the first LM311 to effectively bar the clock noise from triggering spurious counts in the VIDEO COUNTERS. The revised video A-to-D circuit consists of comparators U7 and U11 in Figure 4.3.

3. DIGITAL VIDEO COUNTER STAGES

The VIDEO COUNTERS, consisting of U8 and U9 in Figure 4.3, were rather simple to implement once the digital video signal had

been upgraded. Dual, 4-bit, binary, asynchronous counters served the purpose adequately, making 16 bits available with minimal hardware. As a precaution, the digital video is gated to the counters by the signal PRINTLINE to insure only valid video transitions are recorded.

4. F8 HARDWARE INTERFACE REQUIREMENTS

To use the F8 as the THRESHOLD CONTROL UNIT, I/O ports had to be made available for data transfer. The existing ports (4, 5, 8, and 9) were already being used for scanner coordination with the hard and soft copy printing devices. (1) The threshold control requirements could have been implemented through these ports, but it would have taken considerable multiplexing and hardware design. Fortunately the research completed by Medley (2) included the addition of four new I/O ports (10, 11, 12, and 13) to the F8 system. So the only requirement to make these I/O ports available for use was to complete the wiring to a compatible connector. Details are contained in Appendix E.

5. COMBINED THEORY OF OPERATION

During the period that the optimum threshold is being sought, the circuitry of Figure 4.3 operates in the following manner. A value of N generated by the THRESHOLD CONTROL UNIT (F8) is applied to pins 4 through 13 of U1. The voltage threshold value V0 is obtained from the division between Vref and V2 by resistors R2 and R3. The voltage threshold level, with the

---

(1) See Aghamohammadi, Chapter 7.

(2) Reference Chapter 7.

degree of hysteresis controlled by R11, is applied to the non-inverting input of U7 while the analog video signal from the CCD is applied to the inverting input. The digitized video is then fed through a non-inverting comparator stage provided by U11 with threshold fixed at 2.5 volts to help remove digitized clock noise. The clean digital video is then gated by PRINTLINE through U10 into cascaded counters U9 and U8. For a given line of video, the number of black/white transitions in the digital video signal can be read from the counters to ports 10 and 11 of the F8. Once the optimum threshold has been found, the value is loaded to ports 12 and 13 and valid digitized video passes off the board via pin C for synchronization and hard-copy printing. The outputs of U8 and U9 are now ignored.

6. SCANNER CIRCUIT BOARD RELOCATIONS

During the course of this project, inter-circuit interference due to clocking noise and physical separation of several critical circuit boards degraded system performance to the extent that several circuit boards had to be moved in order to shorten the connections containing critical signals. These relocations are documented in Appendix E.

CHAPTER 5

SAMPLING ALGORITHMS

In this chapter, the procedures for finding the VTC peak are discussed in detail. The purpose of this phase of research was to design a method whereby the THRESHOLD CONTROL UNIT could, in the most efficient manner possible, search the entire range of possible threshold values, [N = 0 to N = 1024], and find that value of N corresponding to the peak of the video transition count, VTC. The major constraint on this design was to keep the algoritnm simple enough to be easily implemented on the F8 microprocessor. At one extreme, the algorithm could entail stepping through every value of N and doing a simple comparison of the present value of VTC and the maximum preceding value of VTC (called MTC) to find the VTC peak. In fact this method was used in gathering the data for Chapter 3. The obvious drawback, however, in implementing this procedure in an operational scanner system is the fact that, since each sample requires one scan line of video, a total of 1024 video lines would have to be dedicated to thresholding. With the scanner on the move, that means the CALIBRATION PATTERN would need to be over five inches wide! One can immediately see a way to decrease the number of video lines by recognizing that only a certain span of N (labeled RV in Chapter 3) contains significant VTC information worth sampling.

(1) Recall from Figure 3.1 that when N = 0, the voltage threshold level is greater than the analog video signal which prevents any digital encoding of the video information. VTC therefore is zero until the threshold encounters the span of significant analog

(1) Since the analog video information generally covers a span of 200 to 300 millivolts, and each incremental change in N equates to a one-millivolt shift in the threshold level, the total number of video lines required could be reduced to around 200 to 300. The width of the CALIBRATION PATTERN now must be 1 to 1.5 inches which is still unacceptably large. At the same time the range of N sampled is dangerously small, which would limit the ATC's ability to adapt to drastic changes. So the research centered on finding a feasible algorithm that could cover the largest range of N in the least number of samples. The algorithm explored for implementation with the ATC is detailed below.

A. SUCCESSIVE APPROXIMATION

Under the assumption that the VTC-versus-N curve to be sampled is relatively smooth and has the general shape of Figure 3.1(C), a fairly straightforward approach can be used to pinpoint the VTC peak. When the automatic thresholding sequence is initiated, the idea is to start with a large step size (increments) for N and take a small number of VTC samples over the entire range of N, [0 to 1024]. This will be called the first pass. Since keeping the step size a binary multiple greatly simplifies programming, the initial step size, S1, was chosen as 128. Referring to Figure 5.1, we see that this divides the range [0 to 1024] into eight segments. For reasons that will soon

---

signal. VTC will again be zero once the threshold level is less than the smallest value of the analog signal.

----------PASS 1

N	VTC
128	1
256	1
384	130
512	117
640	0
768	0
896	0

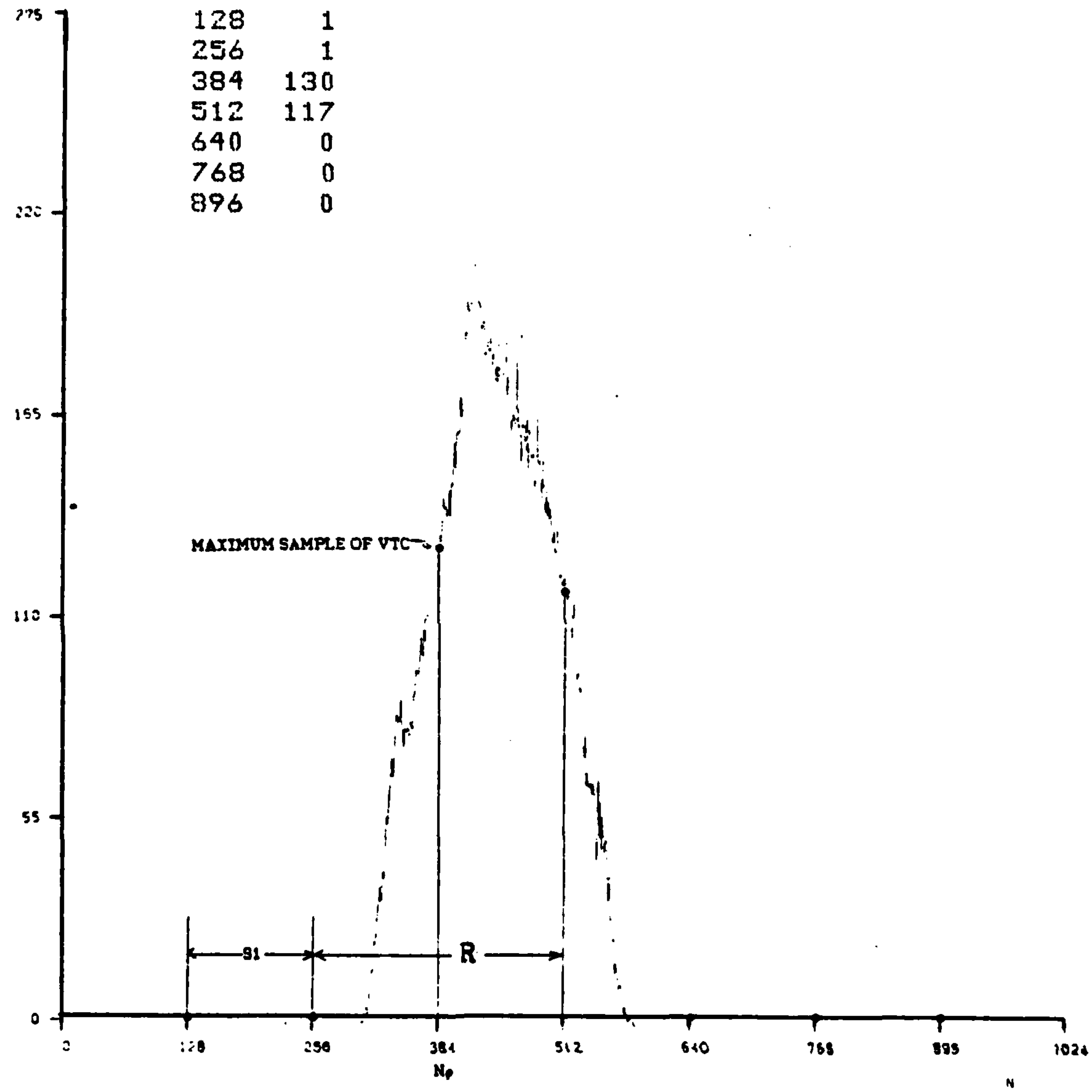


FIGURE 5.1 FIRST PASS OF ATC SAMPLING ALGORITHM QSET1

become apparent, the end points, N = 0 and N = 1024, are ignored, and seven samples of VTC are taken beginning at N = 128. For those samples, the value of N giving the maximum VTC, called Np, becomes the middle of a new range, R, to be sampled with the end points defined as (Np-S1) and (Np+S1), as shown in Figure 5.2. Note that R = 2 x S1. The new range R is now divided into eight segments by using a new step size, S2, which turns out to be equal to S1/4. Again end points are ignored and seven samples are taken at the points shown in Figure 5.2. (1) Repeating the procedure to the limit, it can be seen from Figures 5.3 and 5.4 that a total of four passes or 28 video lines are required to pinpoint the VTC peak within one millivolt. With each video line being 0.05 inch wide, the procedure requires 0.14 inch of CALIBRATION PATTERN to find the optimum threshold value. This width is considered to be acceptable in the context of the amount of margin of the original document required for threshold-setting purposes.

The complete algorithm summarizing the above procedure is flowcharted in Figure 5.5. Block 1 initializes the necessary registers for the overall algorithm, and Block 2 initializes the video line counter for each new pass of 7 video lines. Blocks 3

---

(1) Notice that in this case, the end points were sampled in the first pass and therefore do not need to be re-sampled in the second pass. Although the discarded endpoints of the second pass (N = 256 and N = 512) do not provide an exact analogy to the discarded endpoints of the first pass (N = 0 and N = 1024), it is still easy to see that excluding N = 0 and N = 1024 does not preclude the segments [0 to 128] or [896 to 1024] from being sampled in a subsequent pass if necessary. In this manner, each pass consists of identical procedures.

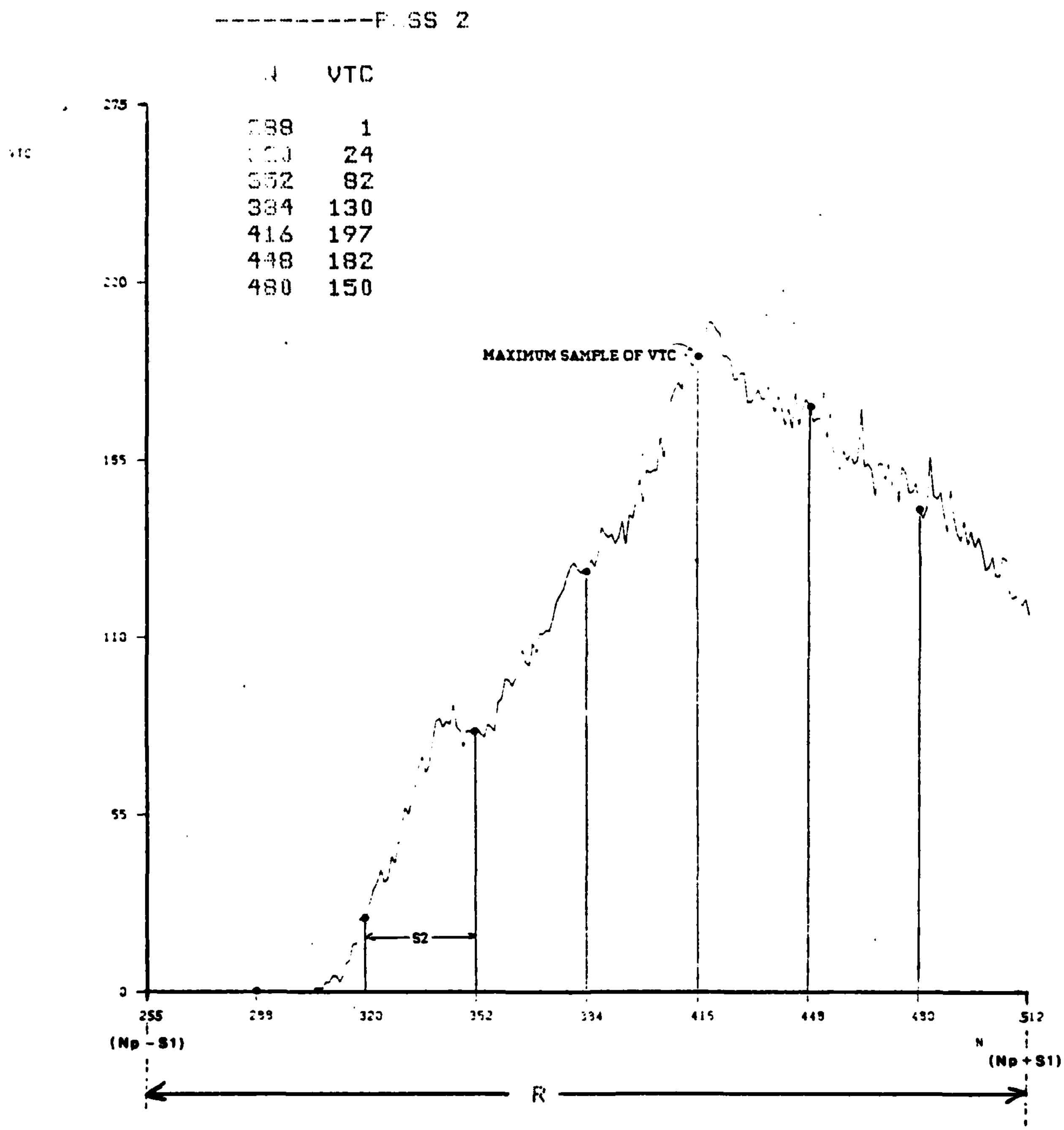


FIGURE 5.2 SECOND PASS OF ATC SAMPLING ALGORITHM QSET1

----------PASS 3

N	VTC
392	139
400	152
408	184
416	197
424	197
432	185
440	181

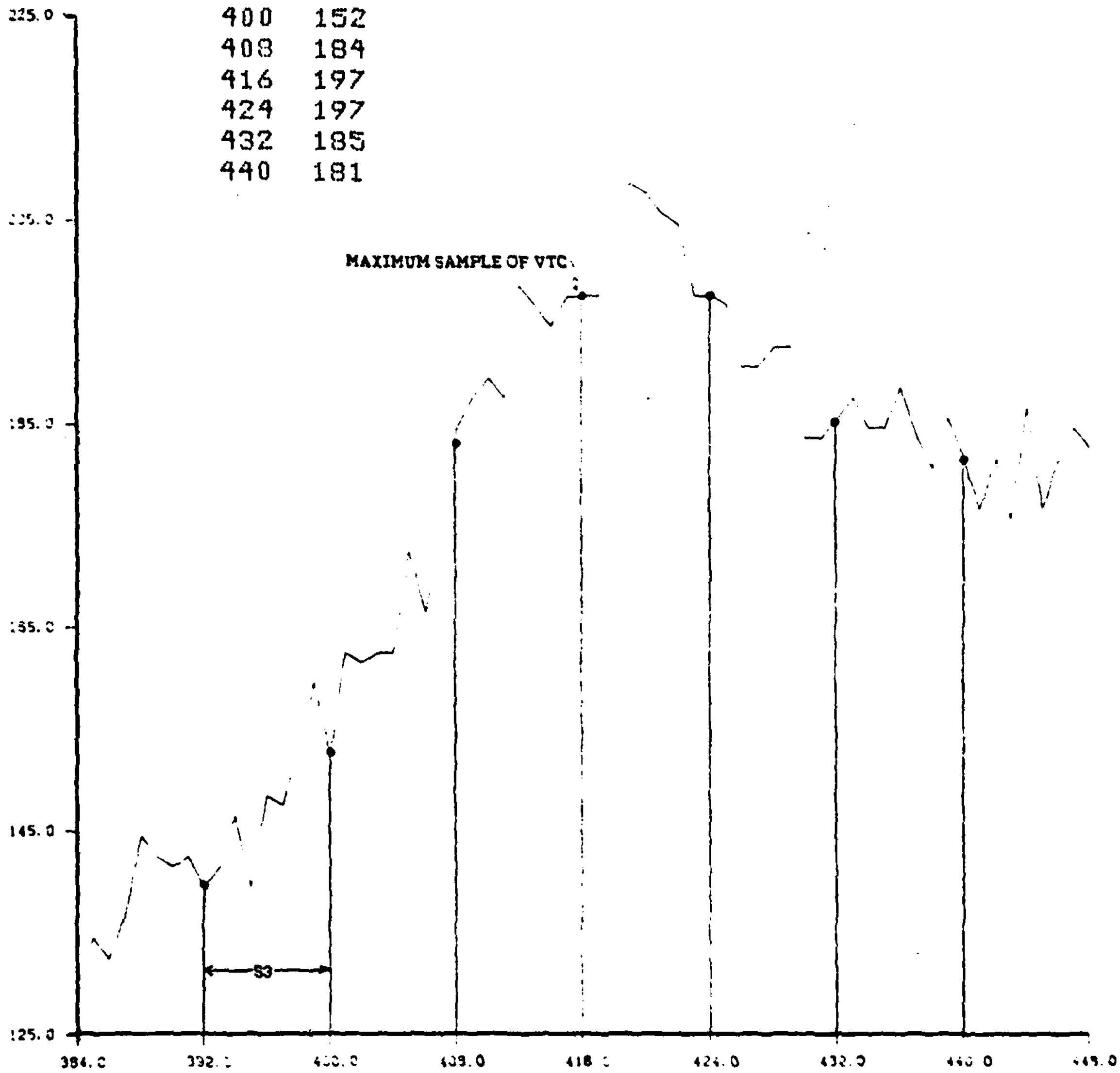


FIGURE 5.3 THIRD PASS OF ATC SAMPLING ALGORITHM QSET1

-----------PASS 4

N	VTC
410	189
412	198
414	194
416	197
418	206
420	207
422	204

THRESHOLD VALUE PRODUCING
PEAK OF VTC CURVE IS: 420

ACTUAL VTC PEAK OCCURRED AT N = 419

ERROR FROM CORRECT N IS: 1

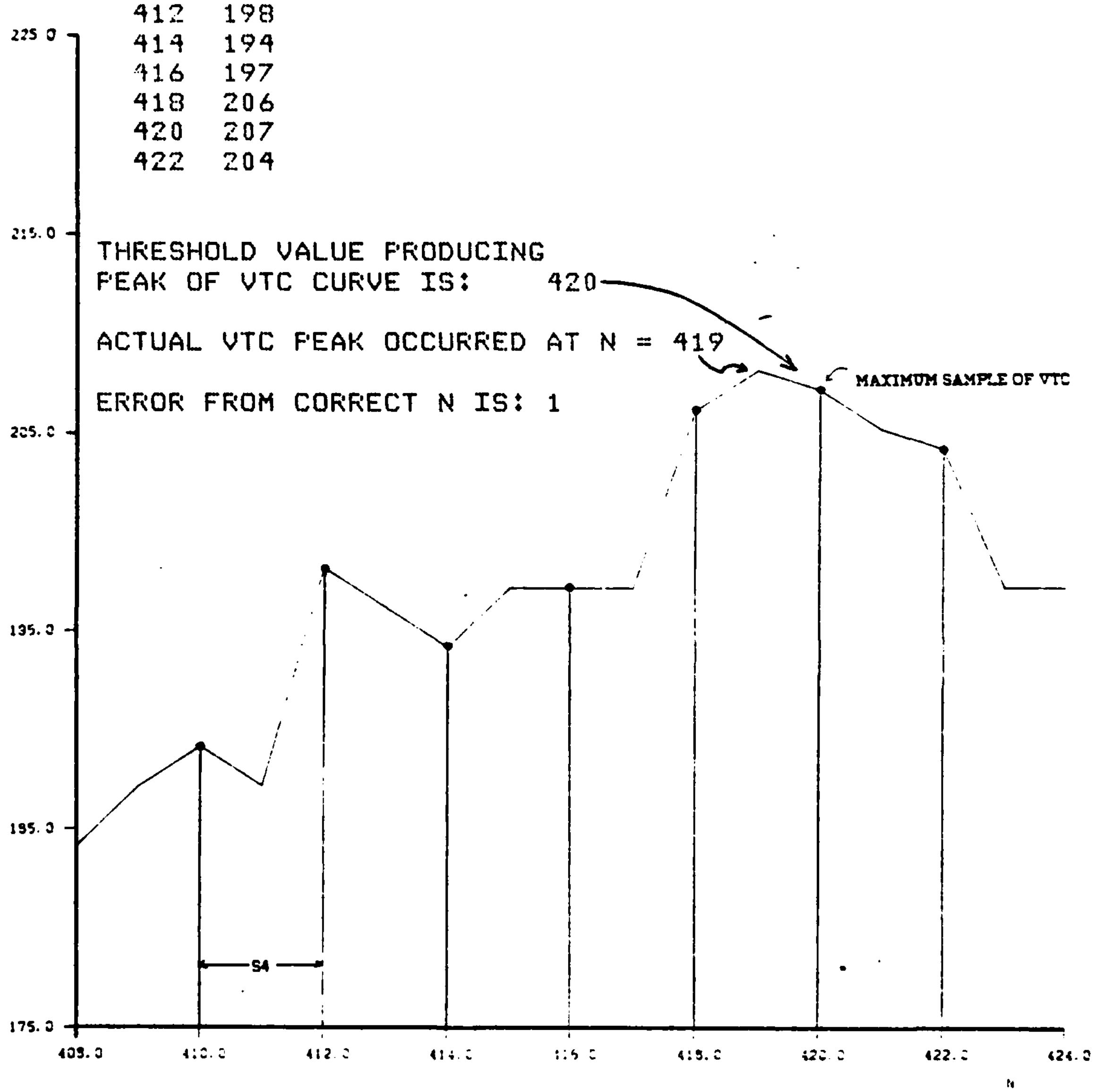


FIGURE 5.4 FOURTH PASS OF ATC SAMPLING ALGORITHM QSET1

through 7 are executed for every line of video. In Block 3 the VIDEO COUNTERS of Figure 4.1 are set to zero, and in Block 4, N is incremented by the existing step size. When PRINTLINE goes active signifying valid video is being transmitted, the digital black/white transitions are counted in Block 5. (1) At the end of the video line, the number of black/white transitions obtained is subtracted from the previous maximum number of transitions. If the result is negative, this means that the VTC just obtained is greater than any VTC previously obtained. Therefore this value of VTC is retained in MTC as the new maximum transition count encountered thus far, and the value of N producing this maximum VTC is also saved. Block 7 counts the number of video lines taken in a particular pass, and the flow is transferred back to Block 3 until the 7 lines of one pass have been completed. For each new pass, Block 8 adjusts the starting value of N for the new range to be sampled, alters the step size, and keeps track of the number of passes executed. At the end of the fourth pass, Block 9 loads the N value that produced the overall maximum VTC into the Threshold Level Generator. This threshold value is used for the entirety of the page being scanned. The algorithm as presented is called QSET1, and computer simulations of QSET1 on actual VTC curves are detailed in Appendix C.

(1) It is important in understanding the sequencing and timing of the algorithm that Block 5 is the only block that is executed during the transmission of valid video information as depicted in Figure 2.1(B). All remaining blocks are executed in the relatively short time gap between successive video lines.

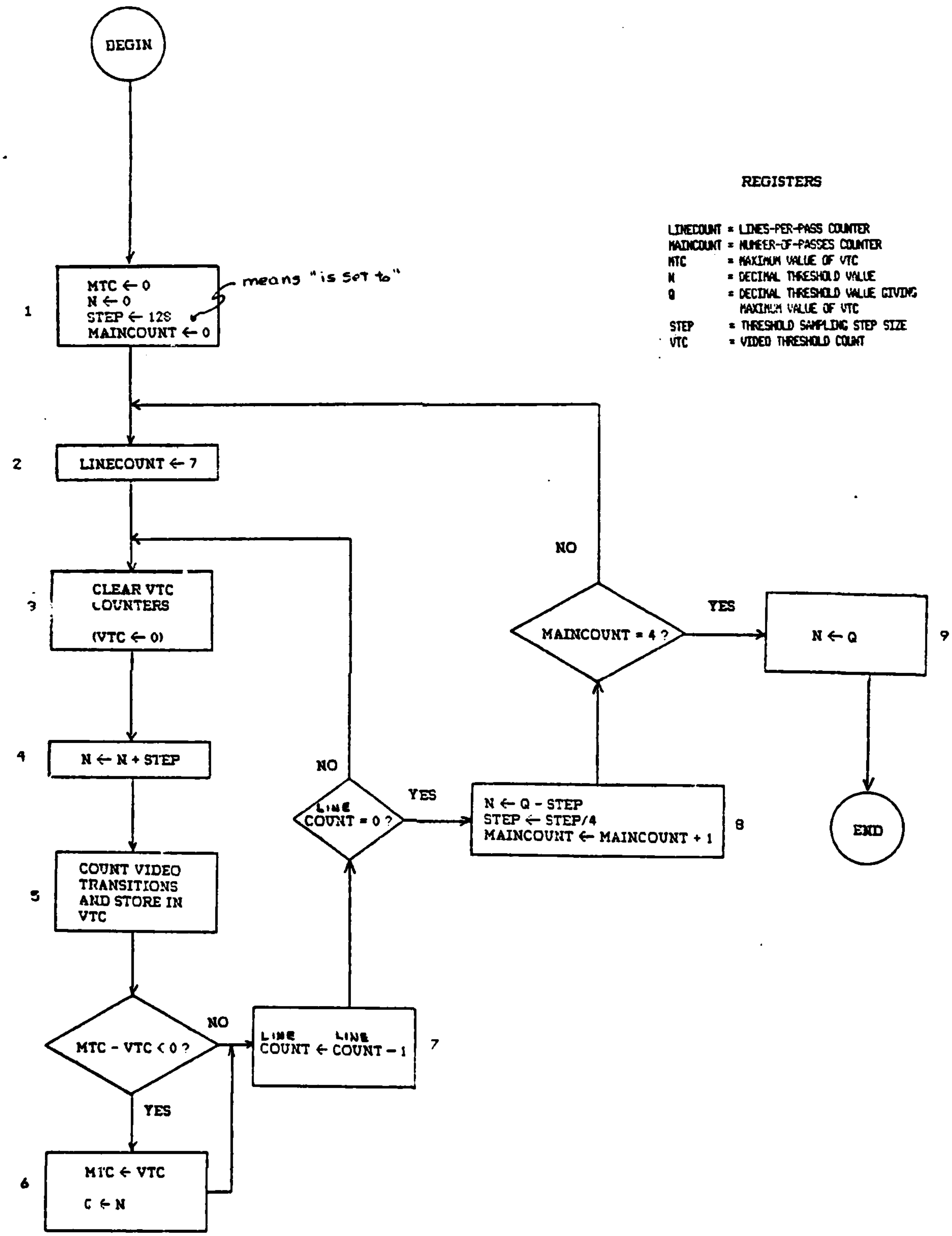


FIGURE 5.5 FLOWCHART OF QSET1 ALGORITHM

B. SAMPLING CONSIDERATIONS

Of prime importance in utilizing a sampling technique such as QSET1 is proper consideration of the initial step size, S1. Specifically, if the range of valid VTC information, RV, is less than S1, then it is possible for all valid VTC information to reside between samples of the first pass as in Figure 5.6. The only instances where the range RV was found to be less than 128 using ECP A were with one-lamp illumination and with the darker paper colors: orange, red, green, brown, and blue. (Remember that f-stop = 5.6 was used throughout the research.) Still, in these cases, the algorithm has the potential of breaking down in its search for the VTC maximum. (1)

The three alternatives to solving the problem of dealing with a small span of VTC information are to either change the voltage range of the TLG, implement a different sampling algorithm, or modify the parameters of the QSET1 algorithm. To maintain a basis for reference throughout this research, the TLG voltage range was not altered although in practice this might be the most reasonable solution. Different sampling algorithms were also considered but rejected due to the additional programming complexity involved. Therefore due to the simplicity of implementation with a microprocessor, the latter alternative was

---

(1) It should now be clear why a single-frequency CALIBRATION PATTERN at the Nyquist rate is not a good choice as implied in Chapter 3. The resultant impulse-like VTC curve having a very small RV would require a prohibitively small initial step size, S1, to detect.

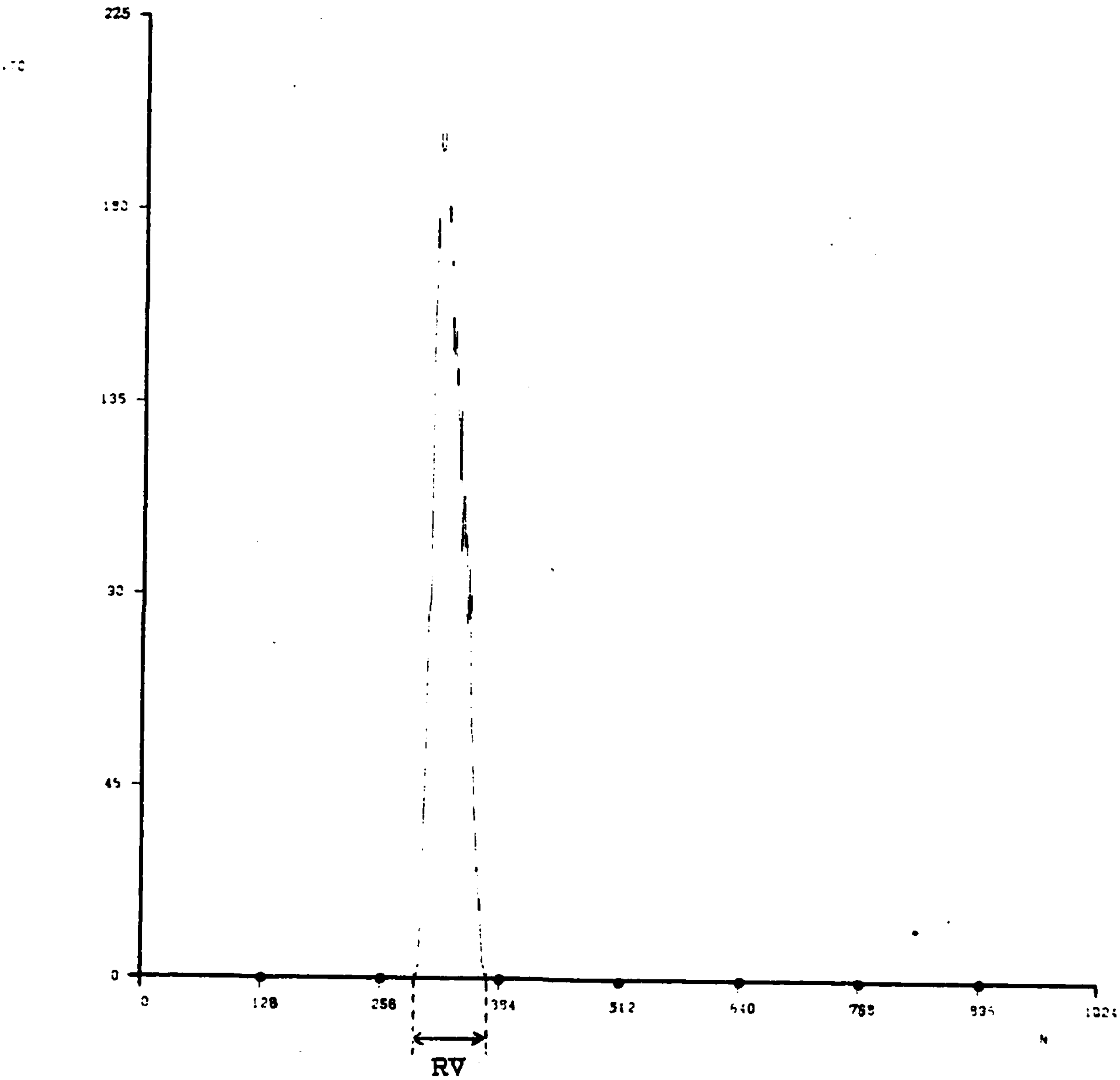


FIGURE 5.6 VTC CURVE PRODUCED FROM SCANNING ECP A ON A RED BACKGROUND. (VTC CURVE IS NEVER FOUND BY QSET1 BECAUSE RV FALLS BETWEEN SAMPLES

preferred for rectifying the problem. Working within the framework of QSET1, the challenge becomes one of decreasing the initial step size, S1, with minimal penalties. Of all experimental observations using ECP A, the smallest span of N over which all VTC values were generated was RV = 67, resulting from navy blue paper. So one possibility is to choose S1 = 64, dividing the range [0 to 1024] into 16 segments, and collecting 15 samples on the first pass. Maintaining 15 samples on subsequent passes results in three passes required in all, or 45 lines of video to set the optimum threshold. Subsequent step sizes would be obtained by dividing by 8:

$$S2 = S1/8 = 8$$
$$S3 = S2/8 = 1$$

Another possibility is to choose S1 = 64 but only collect 7 samples per pass as QSET1 prescribes. This requires the initial sampling range to be cut from 1024 to 512 samples. Maintaining 7 samples per pass results in four passes, or a total of 28 video lines required. Subsequent step sizes are obtained as in QSET1:

$$S2 = S1/4 = 16$$
$$S3 = S2/4 = 4$$
$$S4 = S3/4 = 1$$

In an effort to preserve the small number of video lines used by QSET1, the latter option was chosen. The major compromise was the halving of the overall range of N to be sampled. The impact of this compromise was minimized by using the knowledge of the behavior of the analog video signal to select the starting and ending values of the sampling range as N = 128 and N = 640.

Implemented in the algorithm, QSET2, these choices produced robust performance throughout the range of abnormal paper colors and lighting conditions. The flowchart for QSET2 is identical to that of QSET1 in Figure 5.5 except for Block 1 which becomes:

```
MTC ← 0
N ← 128
STEP ← 64
MAINCOUNT ← 0
```

Another sampling consideration deals with the performance of the QSET algorithm with VTC curves having peaks that are less well-defined. The primary factor that can cause an obscuration of the actual VTC peak is the uncertainty discussed in Chapter 3 and depicted in Figure 3.18. As long as the degree of uncertainty is relatively small, as is the case with ECP A in Figure 3.6(A), the algorithm is quite successful in locating the peak. But if the uncertainty is a significant component of the VTC curve as in Figure 3.12, the results of the algorithm search are not as consistent; the final N value produced by the algorithm becomes more a function of how the samples fall along the VTC curve. These effects are covered more extensively in Appendix C.

C. INCORPORATION WITH SCANNER PRINT SEQUENCE

Once the QSET algorithm was perfected, the next step consisted of adding the necessary software to the F8 program, EOPS (electro-optical page scanner). Since all pertinent F8 source codes are contained in Appendix B, the discussion here will be restricted to the block level. Figure 5.7 is a

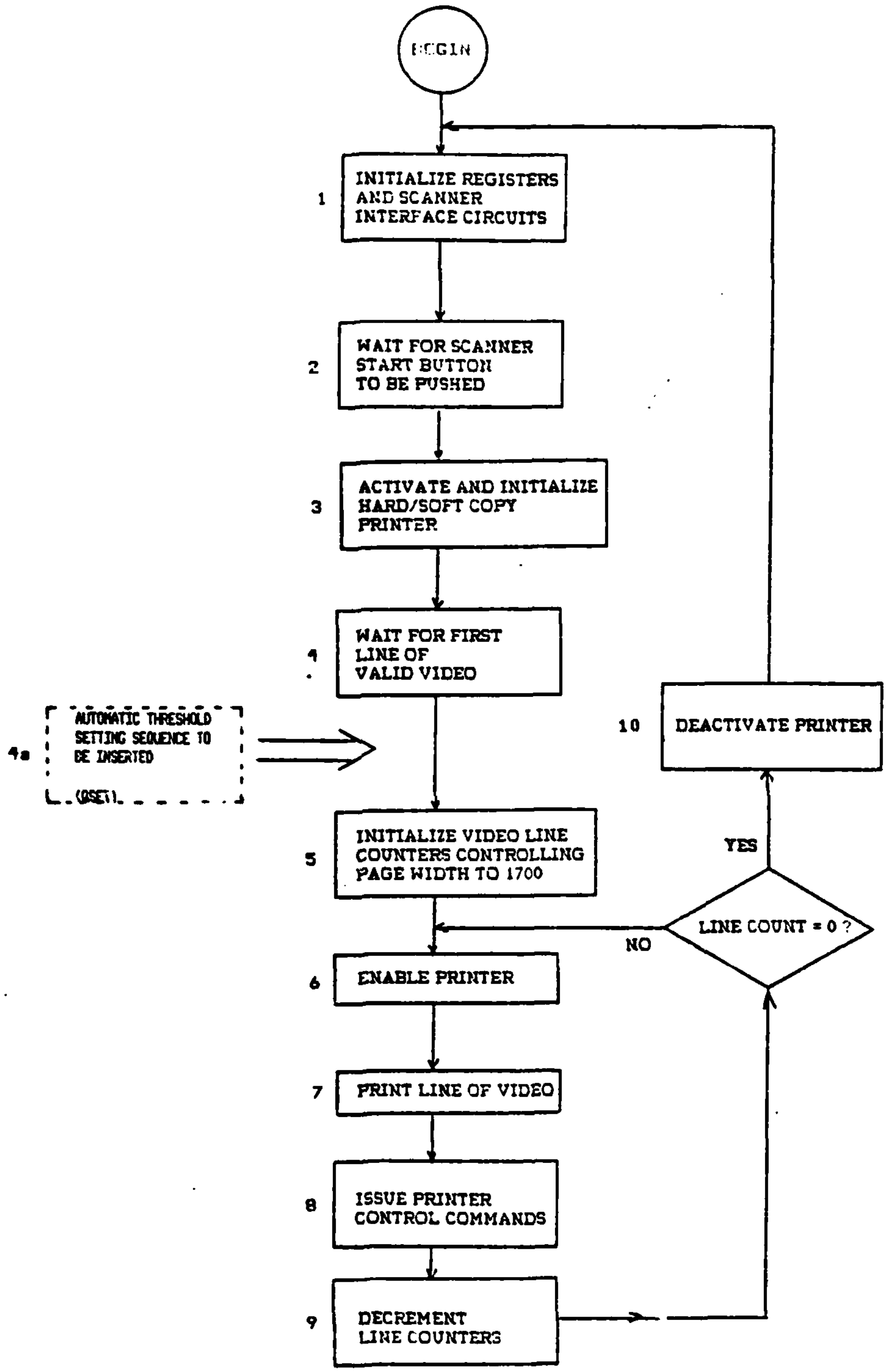


FIGURE 5.7 SIMPLIFIED FLOWCHART OF EXISTING F8 SOFTWARE (EOPS) FOR THE SCANNER

simplified flowchart of the existing scanner algorithm. As stated in Chapter 3, placement of the CALIBRATION PATTERN in the left-most margin allows the first lines of video to provide the necessary information for threshold-setting purposes. Therefore it was necessary for the ATC sequence to be located between Blocks 4 and 5 of Figure 5.7 in order to catch the first lines of valid video. This configuration also turned out to be the most advantageous in terms of software modifications required. With Block 4a included in the flow, the sequence of scanning a document now becomes:

1. After positioning the document, the operator pushes the scanner start button.
2. A start-up delay of just over 1.5 seconds is initiated which allows the fluorescent lights to preheat and the phase-locked loop motor control to stabilize. This delay is accomplished by counting a preset number of pulses generated by the phase-locked loop rate-feedback wheel. Video information is ignored during this time because of the status of the signal PRINTLINE.
3. At the termination of the start-up delay, PRINTLINE goes active, signalling that valid video is now available.
4. The automatic threshold-setting sequence begins and uses 28 video lines to establish the optimum threshold level.
5. Once the optimum threshold is locked in, the VIDEO LINE COUNTERS are set to 1700, giving a page width of 8.5 inches (200 lines/inch).
6. As the video lines are shot, they are printed in real time with the F8 providing the necessary pacing for the printer.
7. When 1700 lines have been read, the printer is shut down automatically, and the F8 software resets. The scanner mechanical assembly is retracted to its starting point upon activation of a limit switch beyond the right-most margin.

For future research purposes, two new versions of EOPS were produced. EOPS1, containing QSET1, provides ATC that samples the entire range of N, [0 to 1024]. EOPS2, containing QSET2, provides ATC that samples the range of N, [128 to 640].

Additional user-oriented features added to EOPS1 and EOPS2 are detailed in Appendix B.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL RESULTS

The performance of the scanner with automatic threshold control was considered to be excellent, especially in the context of proving the validity of the ATC concept that was developed. Xerox copies of scanner printouts are contained in this chapter, and if degradation due to xeroxing is ignored, the results are very good. Figures 6.1 to 6.5 represent consecutive scanner outputs of the same image with the automatically-chosen threshold value noted. Due to the uncertainty discussed in Chapter 3, each threshold value is somewhat different. Still, it can be seen that every copy possesses a high degree of quality, thereby demonstrating the consistency of the ATC. Observe, for example, the legibility of the 6-point type at the lower left of each reproduction of the IEEE Test Chart. Microscopic inspection of these scanner outputs revealed resolutions very close to 200 lines/inch.

Figures 6.6 to 6.8 were produced with EOPS2 and only one fluorescent light providing illumination. Even under the degraded lighting conditions, the ATC was able to select the optimum threshold and produce a very acceptable output. Again note the 6-point type in Figure 6.7 is quite readable.

Figure 6.9 is the result of scanning a transparency of the IEEE Facsimile Test Chart with red paper as a background. Again the threshold level chosen was considered the best possible under

FIGURE 6.1

SCANNER OUTPUT UNDER NORMAL CONDITIONS
(WARM WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 384

FIGURE 6.2
SCANNER OUTPUT UNDER NORMAL CONDITIONS
(WARM WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 403

FIGURE 6.3

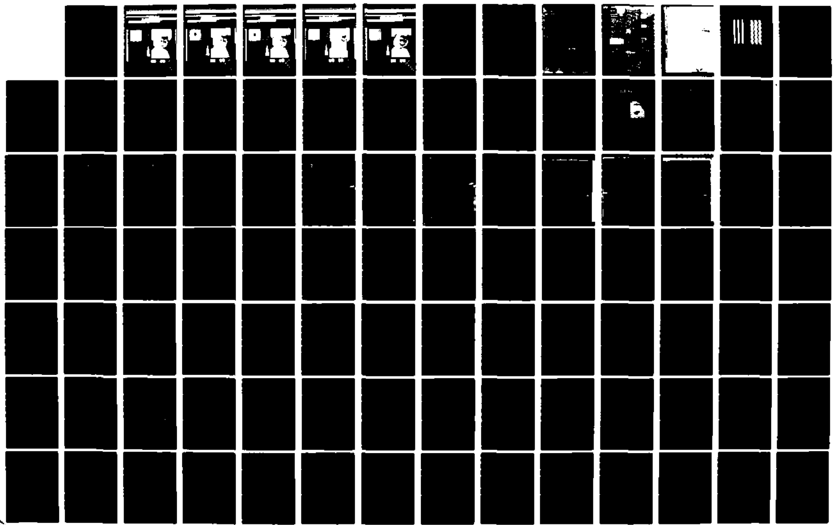
SCANNER OUTPUT UNDER NORMAL CONDITIONS
(WARM WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 393

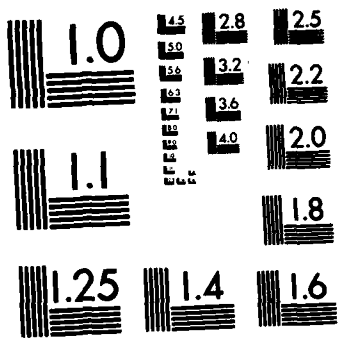
FIGURE 6.4

SCANNER OUTPUT UNDER NORMAL CONDITIONS
(WARM WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 386

AD-A125 316 AUTOMATIC THRESHOLD DESIGN FOR A BOUND DOCUMENT SCANNER 2/3
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH
B J STANTON DEC 82 AFIT-CI/NR-82-71T

UNCLASSIFIED F/G 17/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FIGURE 6.5

SCANNER OUTPUT UNDER NORMAL CONDITIONS (COOL WHITE FLUORESCENTS) THRESHOLD AUTOMATICALLY SET AT N = 395

FIGURE 6.6
SCANNER OUTPUT WITH ONLY ONE COOL WHITE FLUORESCENT LIGHT PROVIDING ILLUMINATION THRESHOLD AUTOMATICALLY SET AT N = 303

FIGURE 6.7
SCANNER OUTPUT WITH ONLY ONE COOL WHITE FLUORESCENT LIGHT PROVIDING ILLUMINATION THRESHOLD AUTOMATICALLY SET AT N = 303

FIGURE 6.8

SCANNER OUTPUT WITH ONLY ONE WARM WHITE FLUORESCENT LIGHT PROVIDING ILLUMINATION THRESHOLD AUTOMATICALLY SET AT N = 320

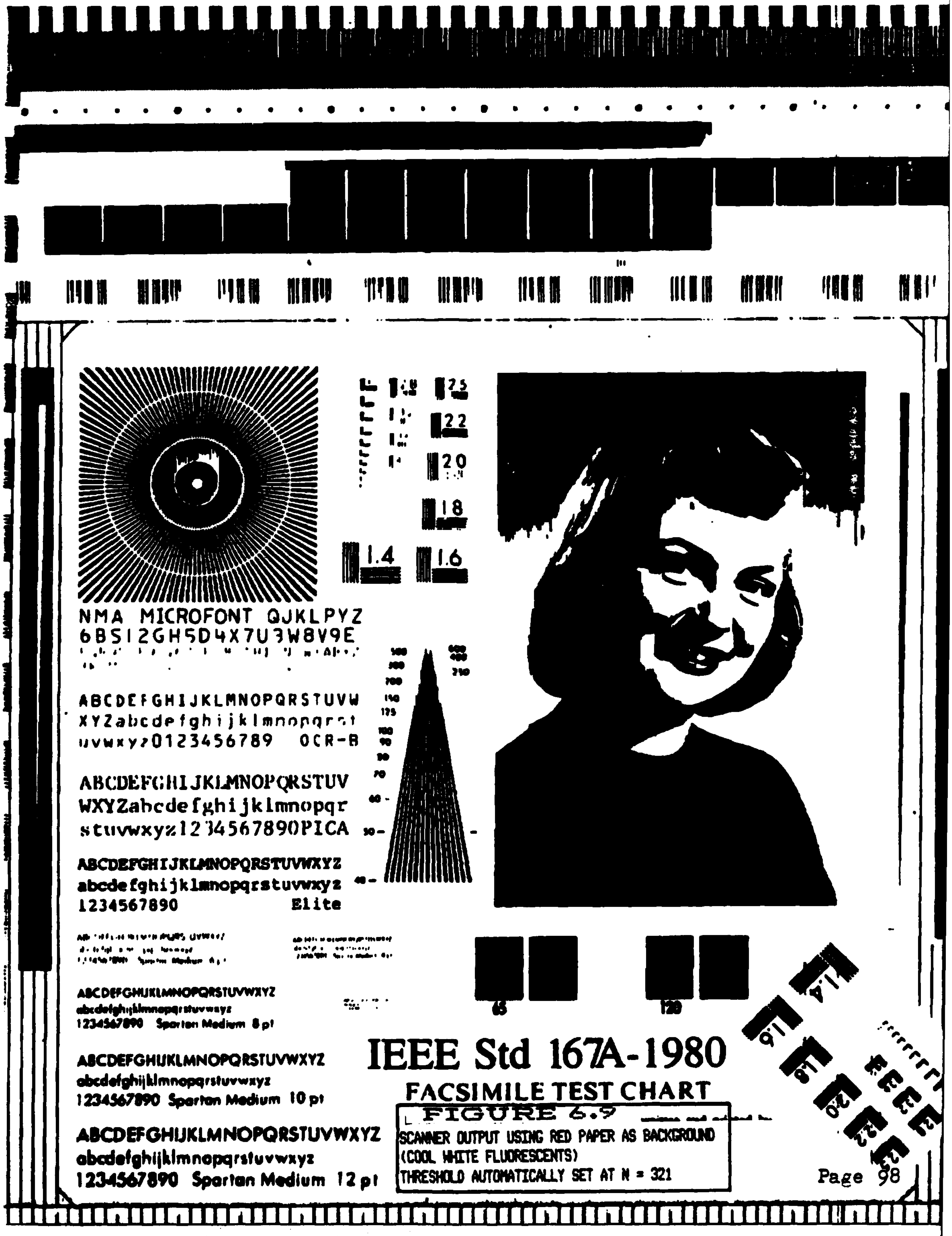


FIGURE 6.9
SCANNER OUTPUT USING RED PAPER AS BACKGROUND
(COOL WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 321

these conditions. This was by far the most demanding test of the ATC because total pel swing of the analog signal was less than 80 millivolts and the threshold level obtained still produced legible copy.

Figures 6.10 to 6.13 represent other document selections for evaluating the Automatic Threshold Control from a subjective standpoint. Figure 6.10 needs no comment, but Figures 6.11 and 6.12 represent fairly difficult text for scanner reproduction. Notice the excellent scanner performance with these documents. The original used to produce Figure 6.13 was a magazine advertisement with a very dark brown background and white print. Although the graphics cannot be interpreted, a majority of the print is legible.

A few points should be discussed concerning the actual limitations of the scanner/printer combination when evaluating the scanner's output. The first point concerns the observed resolution capability of the system. Although the scanner can detect resolutions up to 200 lines/inch, (1) the electrostatic printer used to produce hard copy will not faithfully reproduce this resolution due to the overlapping stylii. As illustrated in Figure 6.14, a resolution of 200 lines/inch will actually have more black than white resulting in a small amount of degradation in the output. Patterns approaching 200 lines/inch will appear

(1) Recall that resolution is measured in lines/inch while spatial frequency is measured in line-pairs/inch. This means there is a 2-to-1 correlation between resolution and spatial frequency. Therefore the CCD Nyquist rate theoretically can produce a resolution of 200 lines/inch.

The Federal Reserve Board could, if it chose, somewhat ease the pain of more business failures by flooding the financial system with money. We do not believe that they will choose this course. The nation has come a long way in winding down inflationary expectations and the Fed is unlikely to give up the fight now. We believe they understand that a critical weapon in the battle against inflation is the reintroduction of "risk" into the economic system. Excessive monetary growth and assured corporate bail-outs do not encourage prudent business planning. Rather, it fosters the immoderate use of borrowed funds and the belief that, in the long run, the ability to raise prices will subsequently justify buying extra inventory or paying excessive wage demands. If the Fed sticks to its guns, business will have to learn how to operate with a totally different philosophy. For some, the lesson will be learned too late.

What else can we look for? Certainly, capital spending plans will continue to be pared back. The latest McGraw-Hill survey of capital spending plans for 1982 pointed to a 3.9% dollar increase, representing a 4 1/2% decline in actual physical outlays. Six months ago, spending plans called for a 1982 advance of 9.6%. Commerce Department surveys have also suggested a scaling back of capital spending intentions. We think the process still has further to go. We expect capital spending to be the weakest sector of the economy until well into 1983 and perhaps for even longer if the economy "triple dips" in early 1983 as we think possible.

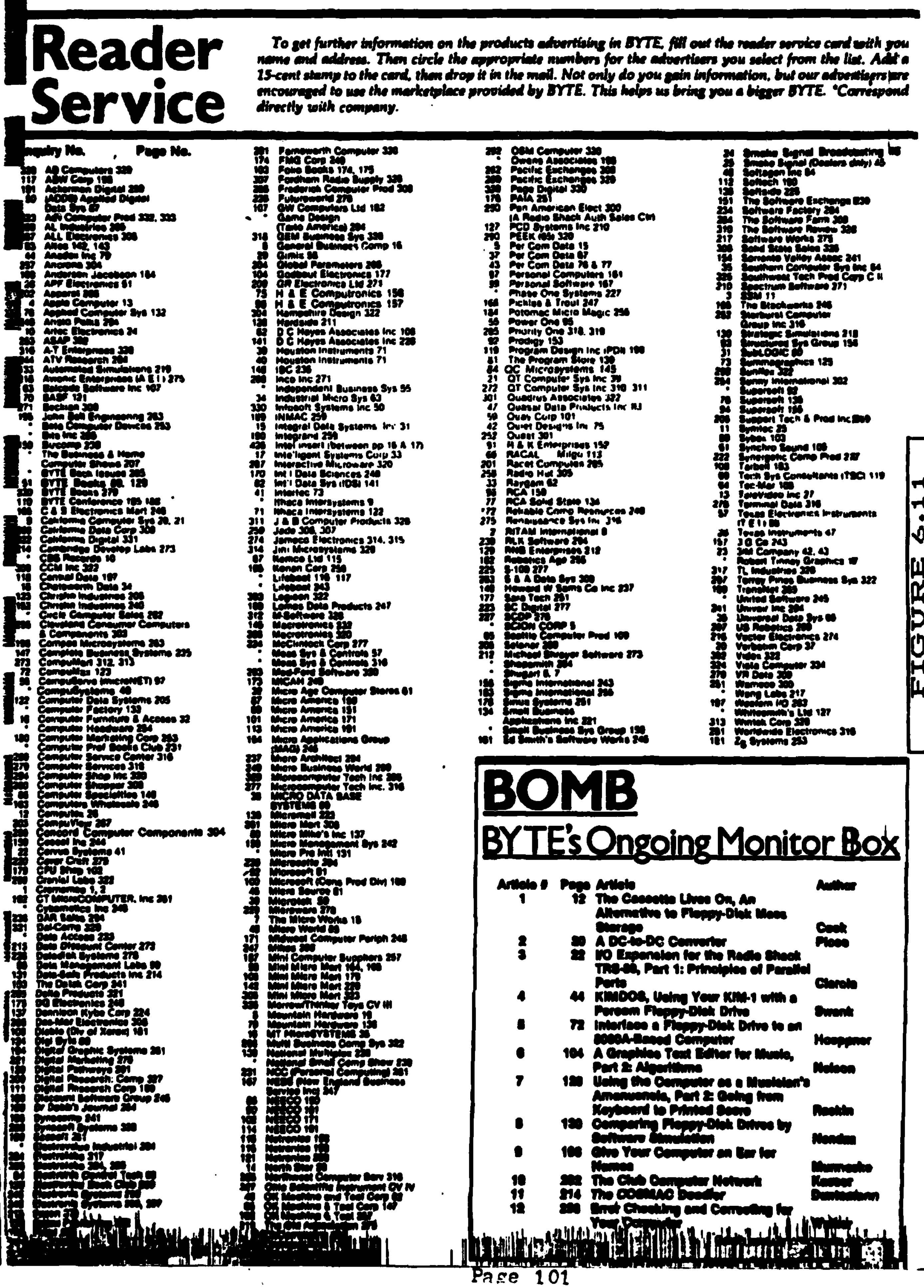
Operating expenses also get cut back when profits are under pressure. The unemployment rate may not have topped out yet although we suspect it doesn't have too much further to go. Wage "givebacks" have characterized labor negotiations in the depressed cyclical industries. Over the next few months we expect the business media to be rife with stories about white collar layoffs and executive salary cuts. Goodrich, for example, recently announced that its top management would take a 15% salary cut while other executives and salaried employees making more than $20,000 a year would take reductions ranging from 5% to 10%.

We also look for a continuation in the surge of dividend cuts as corporations scramble to retain cash. According to Standard & Poor's, through the first 4 months of 1982, 158 companies decreased or omitted their dividend payments, more than twice the number of companies who took similar action last year. In recent months, dividend casualties included such companies as Inland and Republic Steel, Reynolds Metals, Sun Electric, Champion International, Harnischfeger and Manville. Another source of corporate cash is the sale of assets. Dome Petroleum and Inco, among others, have recently announced such plans. Chrysler and International Harvester, of course, have sold off large and profitable divisions. More such moves will follow.

We have painted a rather grim picture of the financial strains on the economy. The reliquefication process is far from complete, a factor which will serve to slow the recovery process. Thus, for this and other reasons, our investment posture with regard to equities has been selective and opportunistic within a generally cautious framework. Companies with sound balance sheets and well-assured prospects of unit growth could do surprisingly well in a restrictive economic environment. Moreover, during uncertain times, some stocks get down to extraordinarily attractive prices in terms of their

FIGURE 6.10

SCANNER OUTPUT UNDER NORMAL CONDITIONS
(COOL WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 392



Reader Service

*To get further information on the products advertising in BYTE, fill out the reader service card with you name and address. Then circle the appropriate numbers for the advertisers you select from the list. Add a 15-cent stamp to the card, then drop it in the mail. Not only do you gain information, but our advertisers are encouraged to use the marketplace provided by BYTE. This helps us bring you a bigger BYTE. *Correspond directly with company.*

Inquiry No. , Page No.

292	OSM Computer 330
*	Owens Associates 198
262	Pacific Exchanges 308
269	Pacific Exchanges 329
330	Page Digital 330
176	PAIA 291
250	Pan American Elect 300 (A Radio Shack Auth Sales Ctr)
127	PCD Systems Inc 210
290	PEEK (65) 320
5	Per Com Data 15
37	Per Com Data 67
43	Per Com Data 76 & 77
97	Personal Computers 181
95	Personal Software 167
*	Phase One Systems 227
168	Pickles & Trout 247
184	Potomac Micro Magic 256
55	Power One 95
285	Priority One 318, 319
92	Prodigy 153
119	Program Design Inc (PDI) 190
81	The Program Store 139
84	QC Microsystems 145
21	QT Computer Sys Inc 39
272	QT Computer Sys Inc 310, 311
301	Quadrus Associates 322
47	Quasar Data Products Inc 83
59	Quay Corp 101
42	Quiet Designs Inc 75
252	Quest 301
91	R & K Enterprises 152
66	RACAL Milgo 113
201	Racet Computes 285
258	Radio Hut 305
33	Raygam 62
95	RCA 158
77	RCA Solid State 134
172	Reliable Comp Resources 248
275	Renaissance Sys Inc 316
7	RITAM International 8
238	RLK Software 294
129	RNB Enterprises 212
182	Robotics Age 256
225	S-100 277

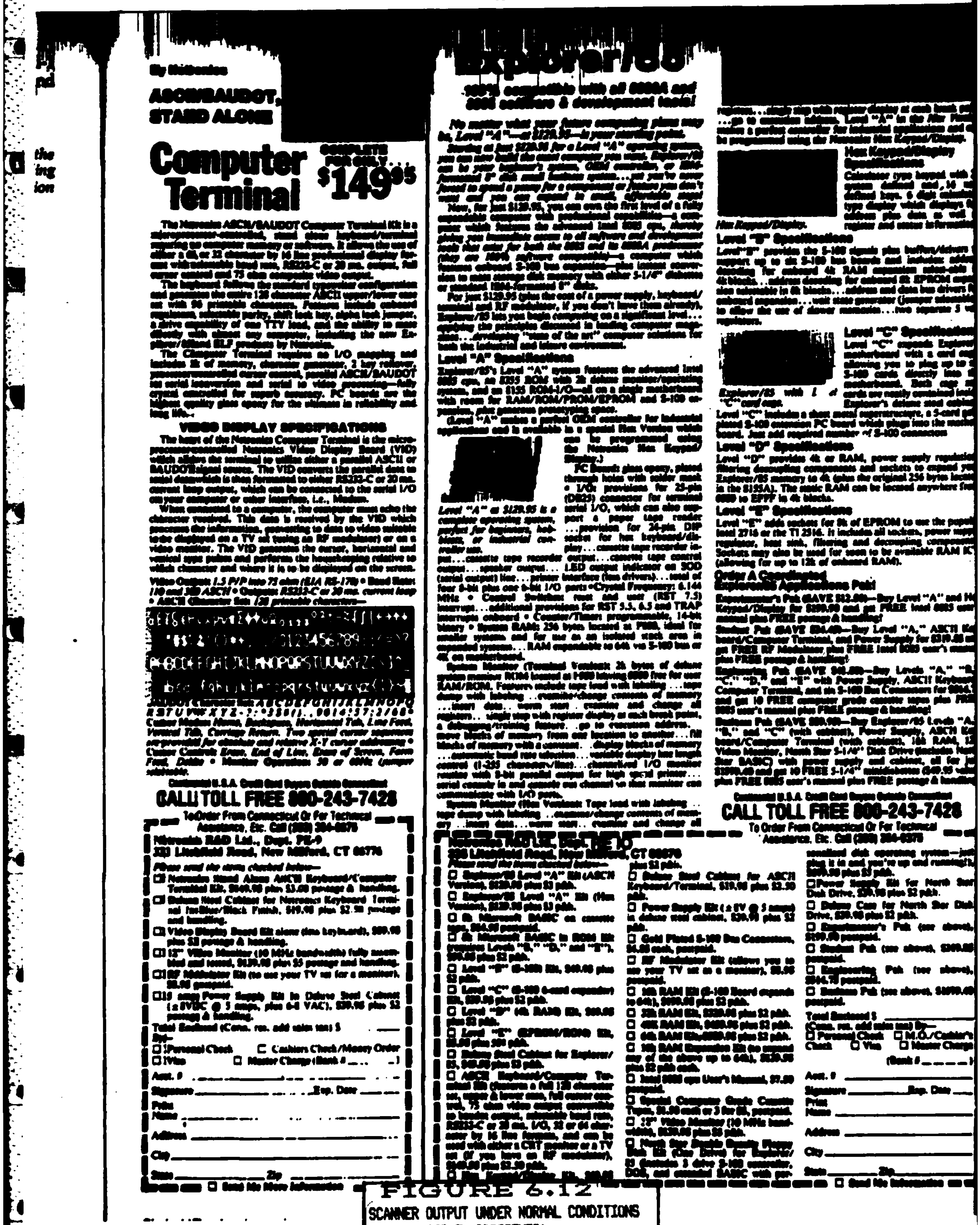
BOMB

BYTE's Ongoing Monitor Box

Article #	Page	Article	Author
1	12	The Cassette Lives On, An Alternative to Floppy-Disk Mass Storage	Cook
2	30	A DC-to-DC Converter	Pleso
3	32	I/O Expansion for the Radio Shack TRS-80, Part 1: Principles of Parallel Ports	Ciarcia
4	44	KIMDOS, Using Your KIM-1 with a Percom Floppy-Disk Drive	Swank
5	72	Interface a Floppy-Disk Drive to an 8080A-Based Computer	Hoeppner
6	104	A Graphics Text Editor for Music, Part 2: Algorithms	Nelson
7	120	Using the Computer as a Musician's Amanuensis, Part 2: Going from Keyboard to Printed Score	Raskin
8	130	Comparing Floppy-Disk Drives by Software Simulation	Hendra
9	166	Give Your Computer an Ear for Names	Murraoka
10	202	The Club Computer Network	Kemer
11	214	The COSMAC Doodler	Danielson
12	250	Error Checking and Correcting for Your Computer	Webb

FIGURE 6.11

SCANNER OUTPUT UNDER NORMAL CONDITIONS
(COOL WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 411



Netronics ASCII/BAUDOT, STAND ALONE

Computer Terminal COMPLETE FOR ONLY... $149.95

The Netronics ASCII/BAUDOT Computer Terminal Kit is a microprocessor-controlled, stand alone keyboard/terminal requiring no computer memory or software.

VIDEO DISPLAY SPECIFICATIONS

CALL TOLL FREE 800-243-7428

To Order From Connecticut Or For Technical Assistance, Etc. Call (203) 354-9375

Netronics R&D Ltd., Dept. PE-9 333 Litchfield Road, New Milford, CT 06776

Explorer/85

100% compatible with all 8080A and 8085 software & development tools!

Level "A" Specifications

Level "B" Specifications

Level "C" Specifications

Level "D" Specifications

Level "E" Specifications

Hex Keypad/Display Specifications

Order A Coordinated Explorer/85 Applications Pak!

CALL TOLL FREE 800-243-7428

To Order From Connecticut Or For Technical Assistance, Etc. Call (203) 354-9375

FIGURE 6.12

SCANNER OUTPUT UNDER NORMAL CONDITIONS
(COOL WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 409

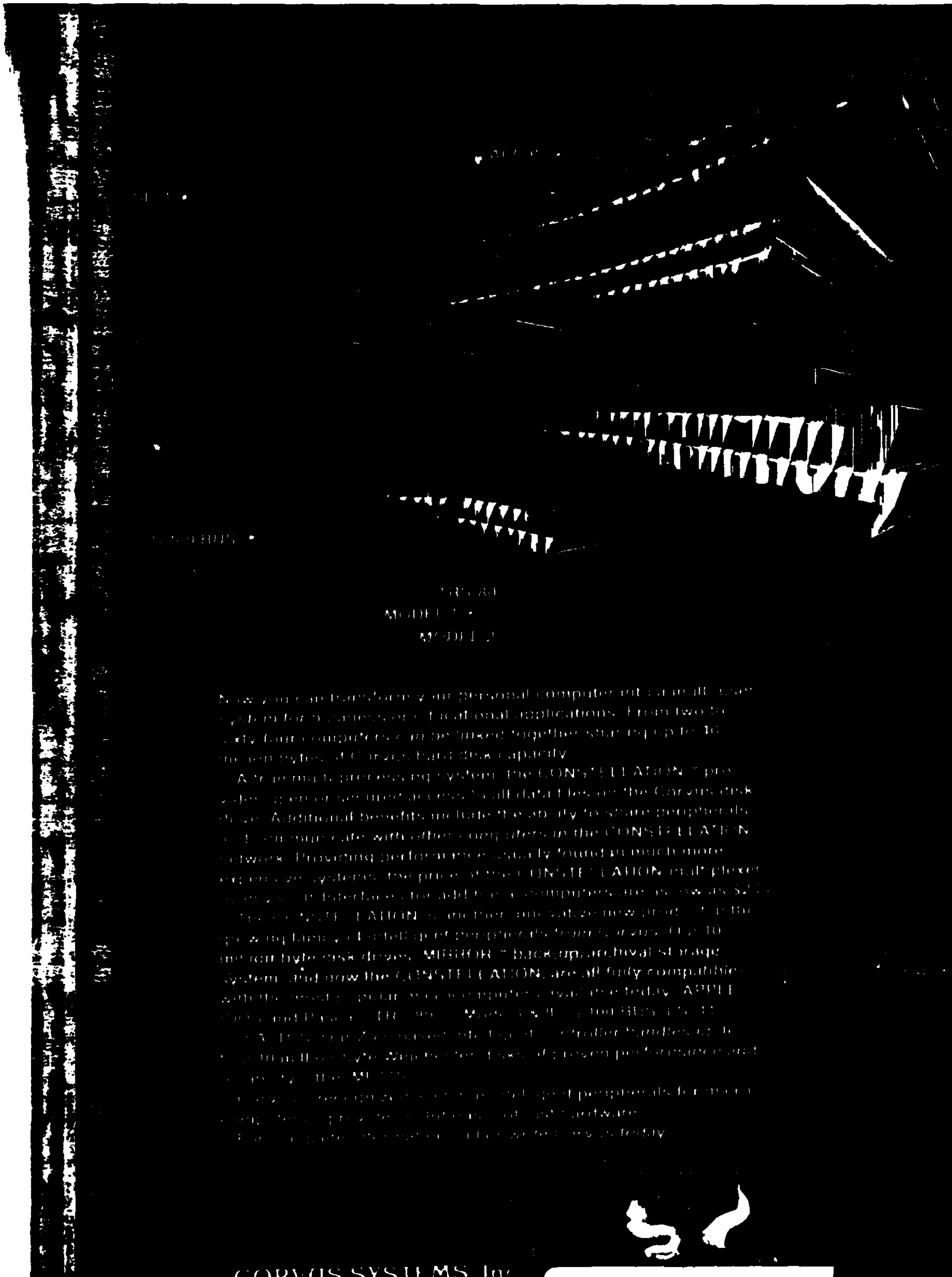


FIGURE 6.13 SCANNER OUTPUT UNDER NORMAL CONDITIONS
(COOL WHITE FLUORESCENTS)
THRESHOLD AUTOMATICALLY SET AT N = 384

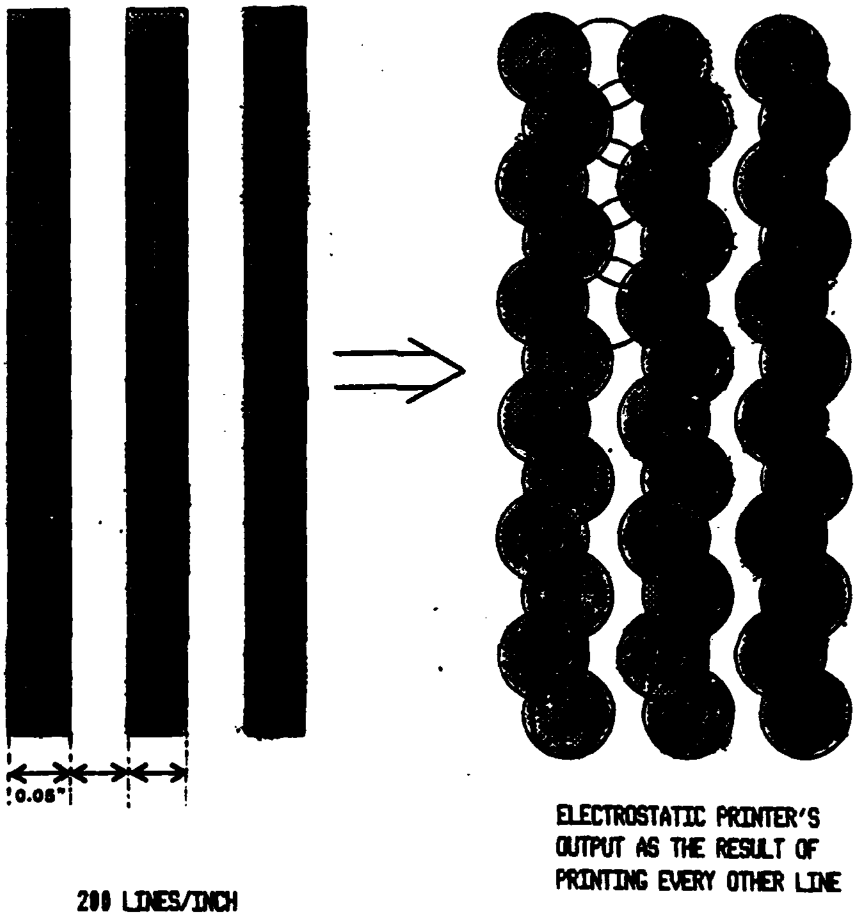


FIGURE 6.14 MAGNIFIED VIEW OF ELECTRO-STATIC PRINTER'S REPRODUCTION OF THE NYQUIST FREQUENCY

to have less white content than they should. This characteristic should be kept in mind when evaluating the resolution of the scanner output with the IEEE Facsimile Test Chart.

The next point deals with the hysteresis included in the video A-to-D converter as an additional measure to prevent clock noise feed-through. The hysteresis was experimentally set at a level that allows all spatial frequencies to be digitized under normal lighting conditions and pastel paper colors. However when abnormal conditions reduce the magnitude of the analog video signal, the pel swing from the highest spatial frequencies are too small to overcome the hysteresis barrier. This effect can be most easily seen with IEEE Test Pattern 12 in Figures 6.6 to 6.9. Distortion due to hysteresis is characterized by a "streaked" or "filled-in" appearance at the affected spatial frequencies.

The last point pertains to the effect of non-uniform illumination. As established in Chapter 3, the ATC will average any light irregularities and select the threshold level giving the highest resolution over the largest portion of the page. This feature of the ATC can be viewed in Figures 6.11 and 6.12. These two copies were produced with fluorescent tubes that had become blackened on the ends due to wear and tear. The ATC still reproduces a majority of the page faithfully with only the bottom of Figure 6.11 and top of Figure 6.12 being degraded because of insufficient light.

B. CONCLUSIONS

In summary, the method produced from this research for automatically selecting the voltage threshold level proved to be successful. The advantages of the ATC are many. First, substantial savings in time, energy, and resources are realized over manual threshold control. Second, the threshold level produced by the ATC is more accurate than one selected by subjective evaluation. Third, the scanner with ATC requires less skills of the user. Fourth, the scanner can automatically respond to a large variety of paper reflectivities and colors. Fifth, light non-uniformities due to deterioration of the fluorescent lamps are automatically compensated. And last, the scanner is able to continue operating automatically with the failure of one fluorescent lamp. On the other hand, a minor disadvantage observed was that the operator must take greater care in placing a document into scanning position to insure the left margin provides background for the CALIBRATION PATTERN.

There are a few critical issues to the proper operation of the ATC that merit discussion. First, it is crucial that the scanner is able to start transmitting video at the same precise physical point for every page. Before ATC incorporation, minor deviations in start position would have hardly been noticeable. But with the need to "see" a narrow CALIBRATION PATTERN in the first few lines, it is now mandatory that the scanner starts reading lines in exactly the same place every time. Inconsistency in the starting position can be offset to a certain

extent by widening the CALIBRATION PATTERN, and this measure was taken by using ECP A which is 0.219 inch wide whereas only 0.140 inch is actually needed. Still a small measure of inaccuracy was observed during research that sporadically caused the CALIBRATION PATTERN to be missed either partially or completely. This resulted in either thresholding errors or a portion of the CALIBRATION PATTERN being printed in the output (called pattern feed-through). This issue will be covered in more detail in the next section.

While established in Chapter 3, another critical issue that deserves repeating is the importance of the design of the CALIBRATION PATTERN itself. The pattern must produce a VTC curve spanning a reasonable amount of N values and producing a clearly definable peak that occurs at the value of N resulting in detection of the highest spatial frequencies. Additionally the CALIBRATION PATTERN should cover the length of the page and have each spatial frequency evenly distributed along its length so that light non-uniformity effects can be minimized.

The other issue that needs review is that of the sampling algorithm design. Not only is it important to maintain a simple scheme due to limitations of the F8 microprocessor, but it is also fundamental to remember that there are less than 900 microseconds available for threshold data processing between video lines. (1) In other words, any algorithm chosen must be able to execute on the F8 in less than 900 microseconds per video

(1) See Figure 2.1.

line. The other point is that as long as the threshold sequence is executed with the scanner in motion, the number of video lines used must be kept to a minimum to preclude the CALIBRATION PATTERN from taking excessive margin space.

C. AREAS FOR FURTHER RESEARCH

1. PHYSICAL POSITIONING ACCURACY

As mentioned earlier, the first line of video in a scan sequence is not necessarily taken from the same physical point each time. It is believed that this was a major cause of thresholding errors encountered during evaluation. To understand the problem, the mechanical sequence must first be studied in Figure 6.15. Once the start button is pushed, the first line of valid video will be transmitted after a preset number of pulses from the phase-locked loop rate-feedback wheel have been counted. Theoretically this should define a very precise distance since the wheel is physically mounted on the lead screw and generates 100 pulses per revolution. It is suspected that errors are being introduced by one or both of the following: either the counters in Block 7, Figure 6.15 are being misloaded by spurious noise, or the mechanical assembly is not coming to rest in exactly the same place each time in Block 8 due to tolerance of the left-most limit switch. This issue should be explored with the purpose of eliminating thresholding errors.

2. CALIBRATION PATTERN

Since this research was conducted with a limited number of available ECPs, a specially designed CALIBRATION PATTERN should

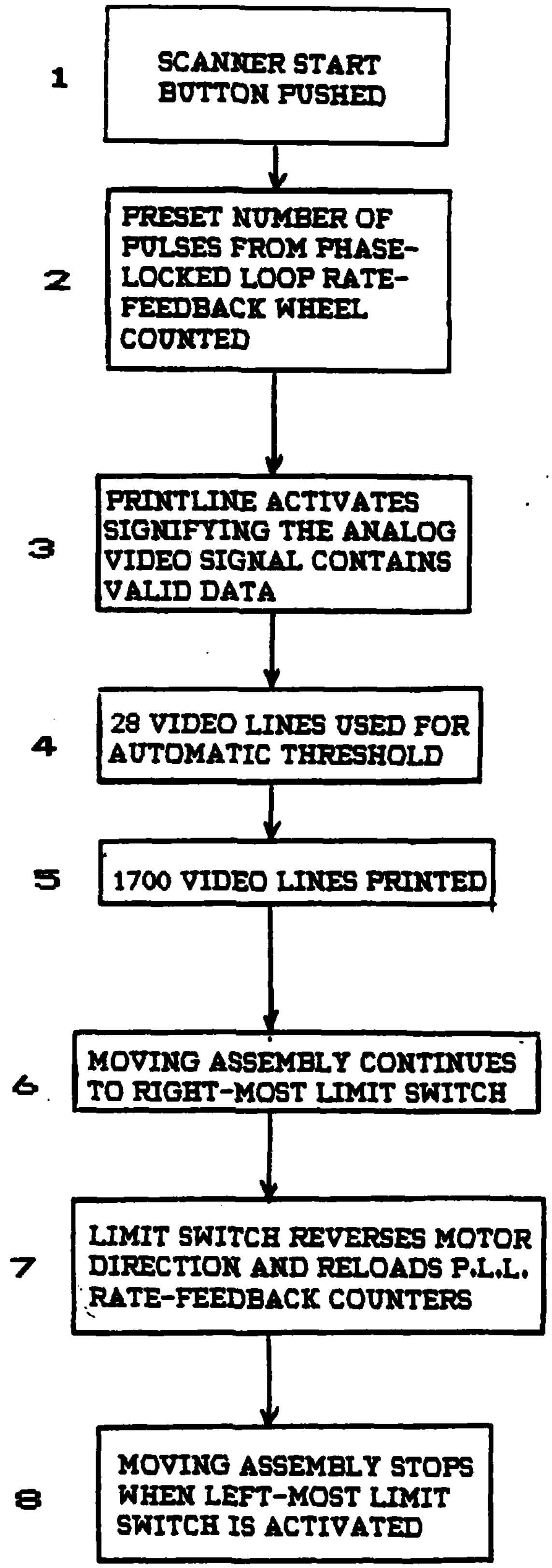


FIGURE 6.15 SCANNER MECHANICAL MOVEMENT SEQUENCE

now be fabricated for use with an operational scanner. Although ECP A works, each frequency burst has only seven discrete spatial frequencies that the CCD can detect; the other five spatial frequencies are above the Nyquist rate and therefore contribute nothing. Additionally, 50% of ECP A has no spatial frequency content whatsoever. In view of this, I suggest designing a CALIBRATION PATTERN specially tailored to the needs of the ATC. Two possible frequency-burst designs are: one with more discrete frequencies, and one containing a linearly increasing set of spatial frequencies. Each burst should be about one inch long and repeated along the length of the page. This effort will not improve the ATC's choice of threshold level since the optimum has already been achieved, but on the other hand, it could further enhance the ATC's robustness under abnormal conditions. Once the operational CALIBRATION PATTERN design has been completed, the pattern itself should be permanently etched into the glass face of the scanner. For expediency in this research, a transparency of ECP A was taped into position to serve the purpose of a CALIBRATION PATTERN.

3. ADJUSTABLE DARKNESS CONTROL

The ATC is designed to select the threshold that will give the most black/white transitions which in turn produces an output that gives equal priority to black and white information. During evaluation however, it was found that, from a subjective standpoint, copies were sometimes more pleasing if the threshold was shifted to slightly blacker than optimum. In this way,

portions of fine print (smaller than 6 point) having spatial frequencies above Nyquist tended to be more readable. The compromise involved the loss of some white information in the form of black fill-in, but this was not a major detraction. Therefore I suggest adding a control whereby the user could bias the threshold to lighter or darker than optimum, depending on the specific need. This could most easily be accomplished by using a multi-position multi-wafer switch configured to feed various 8-bit binary numbers to an F8 I/O part. At the end of the threshold-setting sequence, the F8 would alter the optimum threshold level by the value selected by the user.

4. INK COLOR

Due to time constraints, this research focused only on documents having black print. It is predictable that on a white background, colors of ink other than black will produce a smaller pel swing, but it is unclear what colors of print will not be detected with the threshold level set by the ATC. Future experimentation in this area will better define the capabilities and limitations of the scanner system.

5. SCANNER ILLUMINATION DESIGN

A number of issues concerning the scanner's light source were encountered during the course of this research. (1) First of all, a problem was noted with the light start-up at the beginning of the page-scanning sequence. Either one or both

---

(1) The reader should refer to Aghamohammadi and Agudelo as necessary for background concerning the existing design.

lights failed to illuminate approximately 30 to 40 percent of the time. Start-up failures were more prevalent with:

a. new tubes
b. very old tubes
c. green tubes in general

Secondly, a fairly rapid deterioration at the end of the tubes (1) caused significant non-uniform illumination to occur over the lifetime of the tube. The results of this were seen in Figures 6.11 and 6.12. Thirdly, a significant amount of light leakage (2) into the CCD shifted the analog black level away from absolute black and thereby reduced the effective contrast of the document being scanned.

In view of these difficulties, I suggest that a thorough re-evaluation of the existing illumination design be conducted. This is not necessarily a suggestion to abandon fluorescent tubes for some other type of lamp. On the contrary, there are many advantages of fluorescent lighting to warrant further investigation on obtaining the desired performance with them. One possible source of aggravation for the fluorescent tubes could be the DC drive currently used. While the original idea was to avoid "flicker" problems, it may be a reason for the rapid deterioration and inconsistent start-ups. One alternative is to evaluate the feasibility of using a high-frequency AC drive and incorporating a quarter-wave phase shift between the two tubes.

(1) As discussed in Chapter 3.

(2) As discussed in Chapter 1.

The problem concerning the light leakage can be eliminated by adding a light-proof shroud between the face of the CCD and the focusing lens.

6. SCANNER START BUTTON

Throughout this project, it was noted that the scanner start button was not adequately resistant to various forms of interference. This problem was commonly manifested by the scanner going through one or more uncommanded page-scanning cycles immediately upon completion of a user-initiated page-scanning cycle. Additionally, the scanner would cycle through at least one page-scanning sequence when power was first applied to the system. Although this is not a disabling problem, it is a nuisance that should be corrected before the scanner is placed in a user environment for operational evaluation.

CHAPTER 7

BIBLIOGRAPHY

1. Aghamohammadi, A. "A Design for a Solid State, Opaque-Page Document Scanner", S. M. Thesis, M. I. T., June 1981.

2. Agudelo, G. W., "Development of a Solid-State Bound-Document Scanner", S. M. Thesis, M. I. T., September 1981.

3. Dishop, P. M., "Design of a Data Compression Scheme for a Document Transmission System", S. M. Thesis, M. I. T., September 1982.

4. Keverian, K. M., "An Investigation of Solid State Scanners", S. M. Thesis, M. I. T., September 1980.

5. Medley, R. A., "The Design of a Versatile Microprocessor Software Development Station", S. M. Thesis, M. I. T., August 1981.

6. Reintjes, J. F., and Knudson, D. R., "Investigations of Electronic Interlibrary Resource-Sharing Networks", Project Status Report, December 1979.

7. Reintjes, J. F., "Investigations of Interlibrary Resource-Sharing Networks", Project Status Report, March 1982.

8. Vinciguerra, R. L., "The Analysis and Design of a Data Compressor for a Document Transmission System", S. M. Thesis, M. I. T., November 1981.

APPENDIX A

MANUFACTURER'S TECHNICAL DATA

This appendix contains technical data extracts of pertinent items and components used during the course of this research. This material is included for convenience as reference to support the discussion in the body of this report, and is not meant in any way to serve as a complete set of data. Readers desiring more information should refer to the manufacturers' publications.

FAIRCHILD
A Schlumberger Company

CCD

CCD122/142

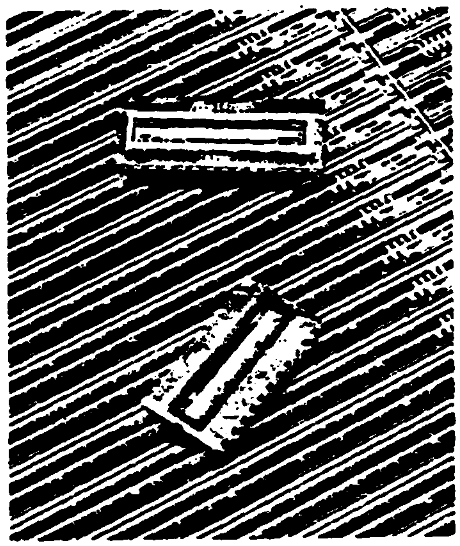
1728/2048-ELEMENT LINEAR IMAGE SENSOR
FAIRCHILD CHARGE COUPLED DEVICE

GENERAL DESCRIPTION—The CCD122 and CCD142 are monolithic 1728 and 2048-element line image sensors, respectively. The devices are designed for page scanning applications including facsimile, optical character recognition and other imaging applications which require high resolution and high sensitivity.

The 1728 sensing elements of the CCD122 provide a 200-line per inch resolution across an 8-1/2 inch page adopted as an international facsimile standard. The 2048 sensing elements of the CCD142 provide an 8-line per millimeter resolution across a 256 millimeter page adopted as the Japanese facsimile standard.

The CCD122 and the CCD142 have overall improved performance compared with the CCD121H including higher sensitivity, an enhanced blue response and a lower dark signal. The devices also incorporate on-chip clock driver circuitry.

The photoelement size is 13 μ (0.51 mils) by 13 μ (0.51 mils) on 13 μ (0.51 mils) centers. The devices are manufactured using Fairchild advanced charge-coupled device n-channel Isoplanar buried-channel technology.



- ENHANCED SPECTRAL RESPONSE (PARTICULARLY IN THE BLUE REGION)
- LOW DARK SIGNAL
- HIGH RESPONSIVITY
- ON-CHIP CLOCK DRIVERS
- DYNAMIC RANGE TYPICAL: 2500:1
- OVER 1V PEAK-TO-PEAK OUTPUT
- DARK AND WHITE REFERENCES CONTAINED IN A SAMPLED-AND-HELD OUTPUT
- SINGLE POWER SUPPLY

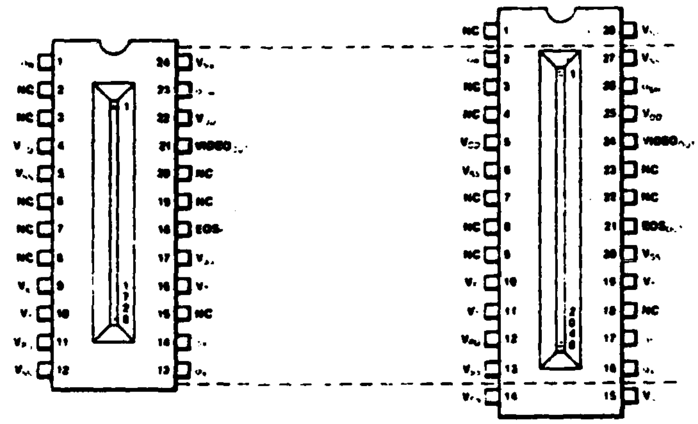
PIN NAMES

V_{PG}	Photogate
ϕ_X	Transfer Clock
ϕ_T	Transport Clock
$VIDEO_{OUT}$	Output Amplifier Source
V_{OD}	Output Amplifier Drain
ϕ_R	Reset Clock
V_{CD}	Clock Driver Drain
V_{EI}	Electrical Input Bias
V_T	Analog Transport Shift Register DC Electrode
EOS_{OUT}	End-of-Scan Output
ϕ_{SH}	Sample-and-Hold Clock
V_{SS}	Substrate (GND)
NC	No Connection (Do not Ground)

CCD122/142 VS. CCD121H COMPARISON

PARAMETER	CCD122/142	CCD121H
Spectral Response — Blue	4:1 Improvement	—
Overall	2:1 Improvement	—
Dark Signal	2:1 Improvement	—
Responsivity	2:1 Improvement	—
On-Chip Clock Drivers	Yes	No
Dark and White References	Yes	No
Single Power Supply	Yes	No

CONNECTION DIAGRAM
DIP (TOP VIEW)



CCD122 CCD142

FUNCTIONAL DESCRIPTION—The CCD122/142 consists of the following functional elements illustrated in the Block Diagram:

Image Sensor Elements — A line of 1728/2048 image sensor elements separated by diffused channel stops and covered by a silicon dioxide surface passivation layer. Image photons pass through the transparent silicon dioxide layer and are absorbed in the single crystal silicon creating hole-electron pairs. The photon generated electrons are accumulated in the photosites. The amount of charge accumulated in each photosite is a linear function of the incident illumination intensity and the integration period. The output signal will vary in an analog manner from a thermally generated noise background at zero illumination to a maximum at saturation under bright illumination.

Transfer Gate — Gate structure adjacent to the line of image sensor elements. The charge-packets accumulated in the image sensor elements are transferred out via the transfer gate to the transport registers whenever the transfer gate voltage goes HIGH. Alternate charge-packets are transferred to the analog transport shift registers. The transfer gate also controls the exposure time for the sensing elements and permits entry of charge to the End-Of-Scan (EOS) shift registers creating the end-of-scan waveform.

Four 879/1039-Bit Analog Shift Registers — Two on each side of the line of image sensor elements and separated from it by the transfer gate. The two inside resisters, called the transport shift registers, are used to move the image generated charge-packets delivered by the transfer gate serially to the charge-detector/amplifier. The complementary phase relationship of the last elements of the two transport shift registers provides for alternate delivery of

charge-packets to establish the original serial sequence of the line of video in the output circuit. The outer two registers serve to deliver the end-of-scan waveform and reduce peripheral electron noise in the inner shift registers.

Gated Charge-Detector/Amplifier — Charge-packets are transported to a precharged diode whose potential changes linearly in response to the quantity of the signal charge delivered. This potential is applied to the gate of an n-channel MOS transistor producing a signal which passes through the sample-and-hold gate to the output at $VIDEO_{OUT}$. The sample-and-hold gate is a switching MOS transistor in the output amplifier that allows the output to be delivered as a sampled-and-held waveform. A reset transistor is driven by the Reset Clock (ϕ_R) and recharges the charge-detector diode capacitance before the arrival of each new signal charge-packet from the transport registers.

Clock Driver Circuitry — Allows the CCD122/142 to be operated using only three external clocks, (1) a Reset Clock signal which controls the integrated output signal amplifier, (2) a square wave Transport Clock which operates at half the reset clock frequency and controls the readout rate of video data from the sensor, and (3) a Transfer Clock pulse which controls exposure time of the sensor. The external clocks should be able to supply TTL level power.

Dark and White Reference Circuitry — Four additional sensing elements at both ends of the 1728/2048 array are covered by opaque metalization. They provide a dark (no illumination) signal reference which is delivered at both ends of the line of video ouptut representing the illuminated 1728/2048 sensor elements (labelled "D" in the block diagram). Also included at one end of the 1728/2048 sense element array is a white signal reference level generator which likewise provides a reference in the output signal (labelled "W" in the block diagram). These reference levels are useful as inputs to external DC restoration and/or automatic gain control circuitry.

DEFINITION OF TERMS:

Charge-Coupled Device — A charge-coupled device is a semiconductor device in which finite isolated charge-packets are transported from one position in the semiconductor to an adjacent position by sequential clocking of an array of gates. The charge-packets are minority carriers with respect to the semiconductor substrate.

Transfer Clock ϕ_X — The voltage waveform applied to the transfer gate to move the accumulated charge from the image sensor elements to the CCD transport shift registers.

Transport Clock ϕ_T — The clock applied to the gates of the CCD transport shift registers to move the charge-packets received from the image sensor elements to the gated charge-detector/amplifier.

Gated Charge-Detector/Amplifier — The output circuit of the CCD122/142 which receives the charge-packets from the CCD transport shift registers and provides a signal voltage proportional to the size of each charge-packet received. Before each new charge-packet is sensed, a reset clock returns the charge-detector voltage to a fixed base level.

Reset Clock ϕ_R — The voltage waveform required to reset the voltage on the charge-detector.

Sample-and-Hold Clock ϕ_{SH} — An internally supplied voltage waveform applied to the sample-and-hold gate in the amplifier to create a continuous sampled video signal at the output. The sample-and-hold feature can be defeated by connecting ϕ_{SH} to V_{DD}.

Dark Reference — Video output level generated from sensing elements covered with opaque metalization providing a reference voltage equivalent to device operation in the dark. Permits use of external dc restoration circuitry.

White Reference — Video output level generated by on-chip circuitry providing a reference voltage permitting external automatic gain control circuitry to be used. The reference voltage is produced by charge-injection under the control of the electrical input bias voltage (V_{EI}). The amplitude of the reference is typically 70% of the saturation output voltage.

Isolation Cell — A site on-chip producing an element in the video output that serves as a buffer between valid video data and dark and white reference signals. The output from an isolation cell contains no valid video information and should be ignored.

Dynamic Range — The saturation exposure divided by the peak-to-peak noise equivalent exposure. (This does not take into account any dark signal components.) Dynamic range is

sometimes defined in terms of rms noise. To compare the two definitions a factor of four to six is generally appropriate in that peak-to-peak noise is approximately equal to four to six times rms noise.

Peak-to-Peak Noise Equivalent Exposure — The exposure level which gives an output signal equal to the peak-to-peak noise level at the output in the dark.

Saturation Exposure — The minimum exposure level that will produce a saturated output signal. Exposure is equal to the light intensity times the photosite integration time.

Charge Transfer Efficiency — Percentage of valid charge information that is transferred between each successive stage of the transport registers.

Spectral Response Range — The spectral band in which the response per unit of radiant power is more than 10% of the peak response.

Responsivity — The output signal voltage per unit exposure for a specified spectral type of radiation. Responsivity equals output voltage divided by exposure level.

Dark Signal — The output signal in the dark caused by thermally generated electrons which is a linear function of integration time and highly sensitive to temperature. (See accompanying photos for details of defintion.)

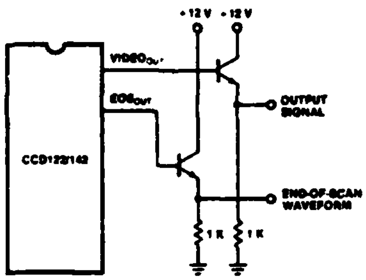
Total Photoresponse Non-Uniformity — The difference of the response levels between the most and least sensitive elements under uniform illumination. (See accompanying photos for details of definition.)

Saturation Output Voltage — The maximum usable signal output voltage, measured from the zero reference level. (See timing diagram.) Any photoelement whose video output < saturation output voltage has an in-spec charge transfer efficiency (CTE). CTE will be below the specification if the video output ≥ saturation output voltage.

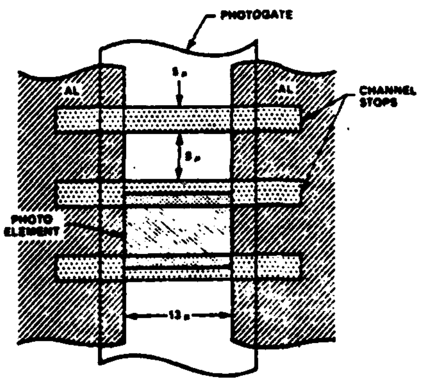
Integration Time — The time interval between the falling edges of any two successive transfer pulses øx as shown in the timing diagram. The integration time is the time allowed for the photosites to collect charge.

Pixel — Picture element (photosite).

TEST LOAD CONFIGURATION



PHOTOELEMENT DIMENSIONS



All dimensions are typical values

ABSOLUTE MAXIMUM RATINGS (Above which useful life may be impaired)

Storage Temperature		−25°C to +125°C
Operating Temperature (See curves)		−25°C to +70°C
CCD122:	Pins 1, 4, 9, 10, 11, 13, 14, 16, 22, 23	−0.3 V to 15 V
	Pins 5, 12, 17, 24	0 V
	Pins 2, 3, 6, 7, 8, 15, 18, 19, 20, 21	NC
CCD142:	Pins 2, 5, 10, 11, 12, 16, 17, 19, 25, 26	−0.3 V to 15 V
	Pins 6, 13, 14, 15, 20, 27, 28	0 V
	Pins 1, 3, 4, 7, 8, 9, 18, 21, 22, 23, 24	NC

CAUTION NOTE: These devices ha limited built-in gate protection. It is recommended that static discharge be controlled and minimized. Care must be take , to avoid shorting pins VIDEOOUT and EOSOUT to VSS or VDD during operation of the devices. Shorting these pins temporari to VSS or VDD may destroy the output amplifiers.

DC CHARACTERISTICS: T_P = 25°C (Note 1)

SYMBOL	CHARACTERISTIC	RANGE MIN	RANGE TYP	RANGE MAX	UNITS	CONDITIONS
V_{CD}	Clock Driver Drain Supply Voltage	12.0	13.0	14.0	V	
I_{CD}	Clock Driver Drain Supply Current		6.9	12.5	mA	
V_{DD}	Output Amplifier Drain Supply Voltage	12.0	13.0	14.0	V	
I_{DD}	Output Amplifier Drain Supply Current		6.9	12.5	mA	
V_{PG}	Photogate Bias Voltage	6.5	7.0	7.5	V	
V_T	DC Electrode Bias Boltage	4.5	5.0	5.5	V	Note 2
V_{EI}	Electrical Input Bias Voltage		11.4		V	Note 3
V_{SS}	Substrate (Ground)		0.0		V	

AC CHARACTERISTICS: (Note 1)
T_P = 25°C, f_{OR} = 0.5 MHz, t_{int} = 10 ms, light source = 2854°K + 3.0 mm thick Corning 1-75 IR-absorbing filter. All operating voltages nominal specified values.

SYMBOL	CHARACTERISTIC	RANGE MIN	RANGE TYP	RANGE MAX	UNITS	CONDITIONS
DR	Dynamic Range					
	(relative to peak-to-peak noise)	250:1	500:1			Note 9
	(relative to rms noise)	1250:1	2500:1			
NEE	RMS Noise Equivalent Exposure		0.0002		μJ/cm²	Note 10
SE	Saturation Exposure		0.4		μJ/cm²	Note 11
CTE	Charge Transfer Efficiency		0.999995			Note 12
V_O	Output DC Level	3.0	5.5	10.0	V	
Z	Output Impedance		1.4	3.0	kΩ	
P	On-Chip Power Dissipation					
	Clock Drivers		90	150	mW	
	Amplifiers		90	150	mW	
N	Peak-to-Peak Noise		2.0		mV	

CCD122/142

CLOCK CHARACTERISTICS: T_P = 25°C (Note 1)

SYMBOL	CHARACTERISTIC	RANGE			UNITS	CONDITIONS
		MIN	TYP	MAX		
$V_{\phi TL}$	Transport Clock LOW	0.0	0.3	0.5	V	Notes 4, 5
$V_{\phi TH}$	Transport Clock HIGH	9.75	10.0	10.5	V	Note 5
$V_{\phi XL}$	Transfer Clock LOW	0.0	0.3	0.5	V	Notes 4, 6
$V_{\phi XH}$	Transfer Clock HIGH	9.75	10.0	10.5	V	Note 6
$V_{\phi RL}$	Reset Clock LOW	0.0	0.3	0.5	V	Note 7
$V_{\phi RH}$	Reset Clock HIGH	9.75	10.0	10.5	V	Note 7
$f_{\phi R}$	Maximum Reset Clock Frequency (Output Data Rate)	1.0	2.0		MHz	Note 8

PERFORMANCE CHARACTERISTICS: (Note 1)
T_P = 25°C, $f_{\phi R}$ = 0.5 MHz, t_{int} = 10 ms, light source = 2854°K + 3.0 mm thick Corning 1-75 IR-absorbing filter. All operating voltages nominal specified values.

SYMBOL	CHARACTERISTIC	RANGE			UNITS	CONDITIONS
		MIN	TYP	MAX		
PRNU*	Photoresponse Non-uniformity					
	Peak-to-Peak		160	210	mV	Note 16
	Peak-to-Peak without Single-Pixel Positive and Negative Pulses		100		mV	Note 16
	Single-pixel Positive Pulses		85		mV	Note 16
	Single-pixel Negative Pulses		130		mV	Note 16
	Register Imbalance ("Odd"/"Even")		20		mV	Note 16
DS	Dark Signal					
	DC Component		5	15	mV	Notes 13, 14
	Low Frequency Component		5	10	mV	Notes 13, 14
SPDSNU	Single-pixel DS Non-uniformity		20	40	mV	Notes 13, 15
R	Responsivity	2.0	3.5	5.0	Volts per $\mu J/cm^2$	Note 17
V_{SAT}	Saturation Output Voltage	800	1400	1600	mV	Note 18

*All PRNU Measurements taken at a 700 mV output level using an f/2.8 lens and excluded the outputs from the first and last elements of the array. The "f" number is defined as the distance from the lens to the array divided by the diameter of the lens aperture. As the f number increases, the resulting more highly columnated light causes the package window aberrations to dominate and increase PRNU. A lower f number results in less columnated light causing device photosite blemishes to dominate the PRNU.

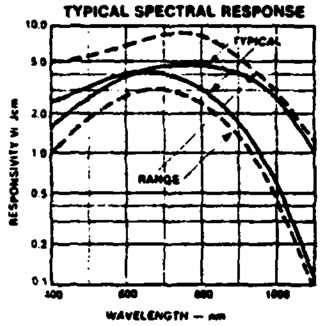
NOTES:

1. T_P is defined as the package temperature.
2. V_T should be equal to (1/2) $V_{\phi TH}$.
3. V_{EI} is used to generate the end-of-scan output and the white reference output. These two signals can be eliminated by connecting V_{EI} to a voltage level equal to $V_{\phi XH}$ + 5 V.
4. Negative transients on any clock pin going below 0.0 V may cause charge-injection which results in an increase of apparent DS.
5. $C_{\phi T}$ = 700 pF
6. $C_{\phi X}$ = 300 pF
7. $C_{\phi R}$ = 5 pF
8. Minimum clock frequency is limited by increase in dark signal.
9. Dynamic range is defined as V_{SAT}/peak-to-peak (temporal) or V_{SAT}/rms noise.
10. 1 $\mu J/cm^2$ = 0.02 fcs at 2854°K, 1 fcs = 50 $\mu J/cm^2$ at 2854°K
11. SE for 2854°K for light without 3.0 mm thick Corning 1-75 IR-absorbing filter is typically 0.8 $\mu J/cm^2$.
12. CTE is the measurement for a one-stage transfer.
13. See photographs for DS definitions.
14. Dark signal component approximately doubles for every 5°C increase in T_P.
15. Each SPDSNU is measured from the DS level adjacent to the base of the SPDSNU. The SPDSNU approximately doubles for every 8°C increase in T_P.
16. See photographs for PRNU definitions.
17. Responsivity for 2854°K light source without 3.0 mm thick Corning 1-75 IR-absorbing filter is typically 2 V per $\mu J/cm^2$.
18. See test load configurations.

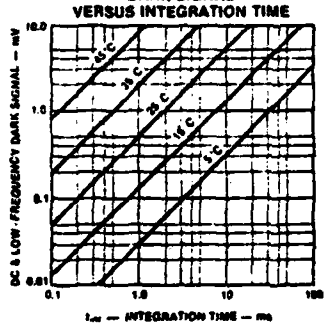
CCD122/142

TYPICAL PERFORMANCE CURVES

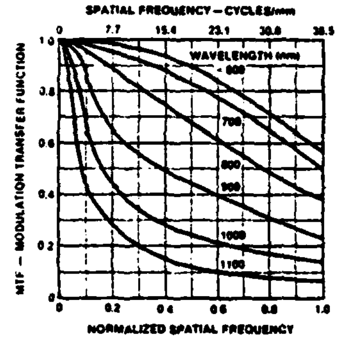
TYPICAL SPECTRAL RESPONSE



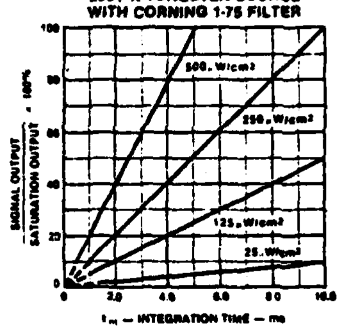
DC AND LOW-FREQUENCY DARK SIGNAL VERSUS INTEGRATION TIME



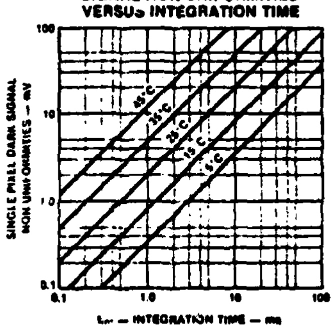
MODULATION TRANSFER FUNCTIONS FOR NARROW BAND ILLUMINATION SOURCES



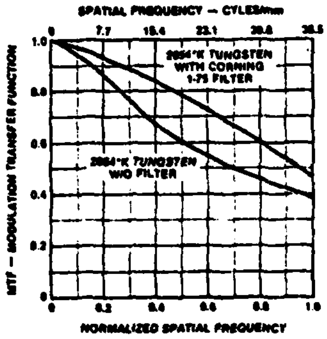
OUTPUT SIGNAL LEVEL VERSUS INTEGRATION TIME 2854°K TUNGSTEN SOURCE WITH CORNING 1-75 FILTER



SINGLE-PIXEL DARK SIGNAL NON-UNIFORMITIES VERSUS INTEGRATION TIME

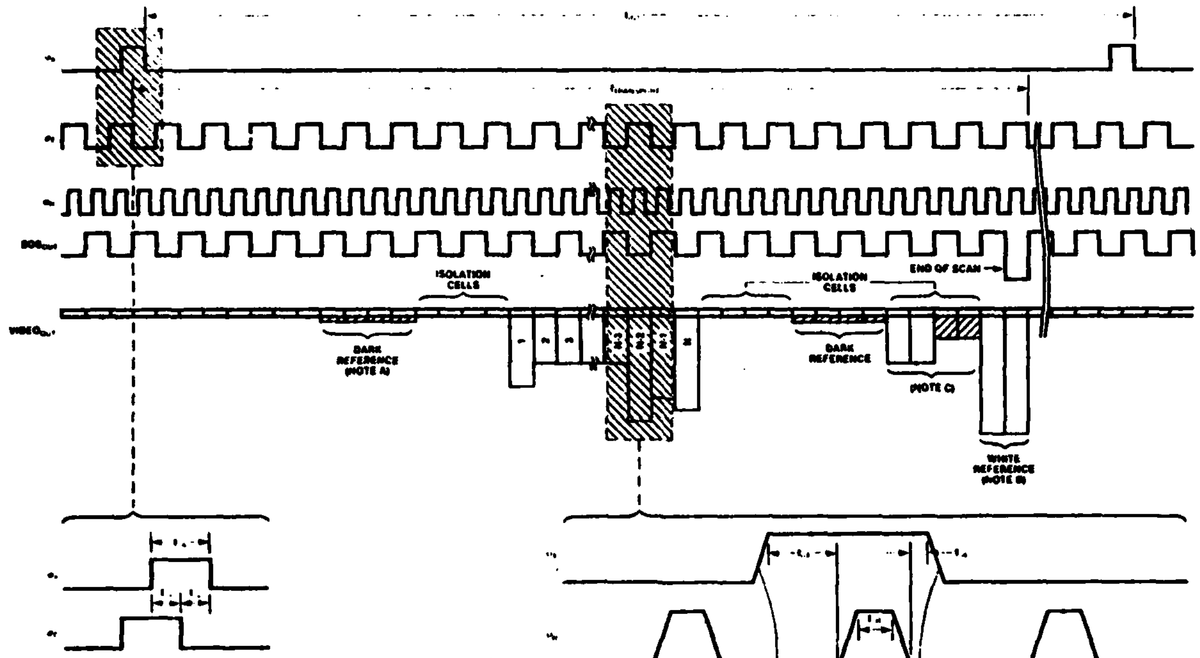


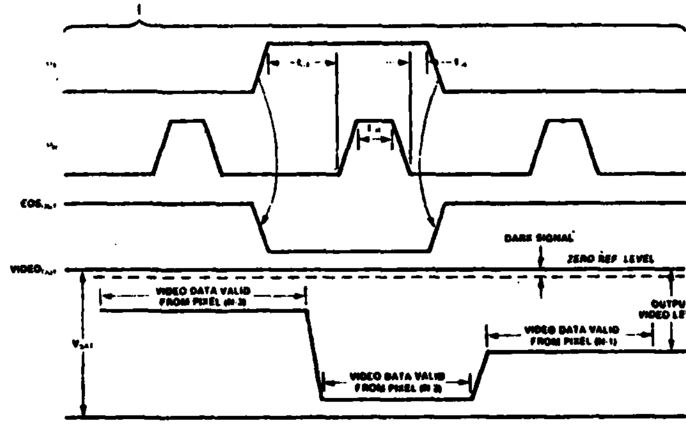
MODULATION TRANSFER FUNCTIONS FOR TWO BROADBAND ILLUMINATION SOURCES



The Corning 1-75 filter has the following typical transmittance spectral characteristic: >85% at < 600 nm, 80% at 700 nm, 30% at 800 nm, 5% at 900 nm and < 2% at > 1000 nm.

TIMING DIAGRAM DRIVE SIGNALS





Timing requirements for transfer pulse ϕ_X (Note D). A ϕ_X pulse must straddle a ϕ_T transition as shown.

$t\phi_X > 200$ ns $t_{e1} > 100$ ns $t\phi_2 > 100$ ns

Timing requirements for reset pulse ϕ_R (Note D)

$t\phi_R > 40$ ns $t_{e3} > 350$ ns $t\phi_4 > 120$ ns

NOTES:

A. The first and last elements of the dark reference signal output may not contain a valid representation of that signal.

B. White reference cell output signals will be approximately equal in height.

C. These isolation cells may contain output signals as part of their buffer function. These signals should be disregarded.

D. Recommended rise and fall times for all clocks are that they are ≥ 20 ns.

IEEE Std 167A-1980
Facsimile Test Chart

Pattern Descriptions

The pattern number given in the following description may be identified from Figure 1. This chart is designed for scanning in either direction, horizontally across the page.

IEEE Std 167-1966, Test Procedure for Facsimile was based on previous issues of the IEEE Test Chart.

Patterns 1 and 2. 96 lines per inch (3.78 lines per millimeter) consisting of 48 dark and 48 light lines, substantially equal in width. In pattern 1, the black corresponds approximately to step 2 and gray to step 7 of pattern 8. In pattern 2, white represents paper white and gray to approximately step 11. These patterns are intended for generating low-modulation high-frequency signals at both ends of the density scale— useful for testing modulation characteristics at edges of band in a frequency shift system.

Patterns 3, 4, and 5. Vertical bar patterns at 10, 50, and 96 lines per inch (0.394, 1.97, and 3.78 lines per millimeter) of substantially equal width — useful for square-wave testing at several keying frequencies.

Pattern 6. A continuous density wedge designed so that at equal intervals of distance across the page, the variation in reflectance will be roughly equally perceptible to the eye. Reading left-to-right across the page, the relative reflection density values at the heavy dots are approximately as shown in Table 1. Pattern 6 is useful for cases where intermediate reflection densities are needed between the steps in Patterns 7 and 8.

Table 1
Pattern 6 Density Values

Dot	1	2	3	4	5	6	7
Density	1.95	1.75	1.28	0.73	0.38	0.14	0.08

Patterns 7 and 8. Reversed step tablets of 15 steps with reflection densities corresponding the approximately equal perceptibility modified to provide smaller low density increments. Consistent with conventional practice, paper white is understood to be equal to 0.00 in density (approximately 0.07 on an absolute scale). For patterns 7 and 8 the relative reflection densities are shown in Tables 2 and 3 respectively.

These patterns will assist in appraising gradient and absolute scale. They are useful for checking half-tone characteristics. Reversed sequences are used since the dynamic halftone characteristics may differ for a rising density or a falling density scale.

Pattern 9. National Bureau of Standards (NBS) type repeating tri-bar resolution test pattern. Twelve complete sets of three-line patterns are repeated across the sheet. Alternate groups are of different line spacing. Density values are shown in Table 4. This pattern is useful for checking definition.

Pattern 10. Rectangle with 45° diagonal marks at each corner — useful for checking index of cooperation, skew, and paper-feed error.

Patterns 11 and 17. White wedge on black background and black wedge on white background, 0.07 in (1.78 mm) to zero — useful for checking single-line definition.

Pattern 12. W. and L. E. Gurley type Pestrecov Star pattern. Outer circle 50, second circle 100, and third circle 200 lines per inch (1.97, 3.94, and 7.87 lines per millimeter).

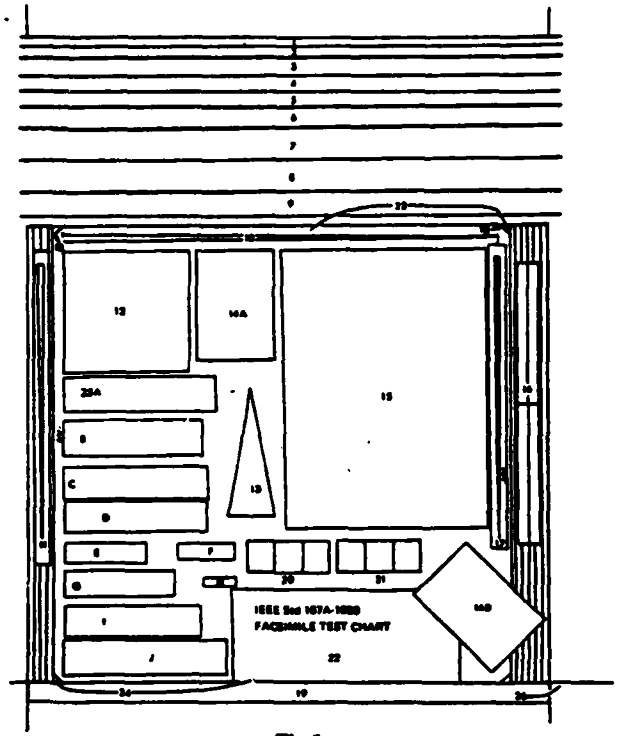


Fig 1
Pattern Arrangement

Pattern 13. Truncated fan-type multiple-line test pattern. Calibrated in lines per inch—useful for checking multiple-line definition along scanning line, envelope delay distortion, and ringing.

Patterns 14A and 14B. NBS type Microcopy Resolution test pattern. Numerals indicate the number of cycles (one black plus one white line) per millimeter (that is, line pairs)—useful in checking high definition systems.

Pattern 15. Photograph with detail in highlight and shadow. The limiting densities of the photograph approximate those of test patterns 7 and 8.

Pattern 16. Vertical gray steps with relative reflection densities of approximately 0.95 and 0.27 — useful in testing rising and falling transient characteristics and level variations.

Pattern 18. Horizontal "V" pattern with 0.13 in (3.3 mm) opening. Number of scanning line crossings of both lines, multiplied by 7.7 will equal number of lines per inch (multiply by 0.3 for number of lines per millimeter).

Pattern 19. "Fence" pattern with 0.01 in (0.254 mm) lines 0.10 in (2.54 mm) apart—useful for checking jitter and measuring available line length.

Patterns 20 and 21. Halftone dot screens. Reproduced in approximately 10, 50 and 90 percent black, left to right and at 65 dots per inch (2.56 dots per millimeter) at a 45° angle for pattern 20, and 120 dots per inch (4.72 dots per millimeter) for pattern 21.

Pattern 22. Title and credit box. Three sizes of Times Roman type font.

Patterns 23 and 24. Fiducial dots forming a 3, 4, 5 right triangle—useful for indicating the presence of skew by comparing the hypotenuse of the two patterns.

Pattern 25. Type faces as indicated—useful for checking readability.

Pattern 26. Extension lines to permit measurement of available line and useful length of copy.

Table 2
Pattern 7 Density Test

Step	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Density	0.01	0.03	0.13	0.25	0.41	0.56	0.70	0.84	0.94	1.05	1.17	1.32	1.49	1.66	1.80

Table 3
Pattern 8 Density Values

Step	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Density	1.70	1.55	1.39	1.25	1.16	1.06	0.94	0.84	0.70	0.56	0.43	0.27	0.15	0.05	0.01

Table 4
Patern 9 Density Values

	Group A						Group B					
	1	2	3	4	5	6	1	2	3	4	5	6
Lines per Inch	61.0	86.4	122	173	244	345	406	284	203	142	102	71.1
Lines per Millimeter	2.40	3.40	4.80	6.81	9.60	13.6	16.0	11.2	7.99	5.59	4.02	2.80

NOTE: Group A has coarse lines starting at the left. Group B has coarse lines starting at the right.

ANALOG DEVICES

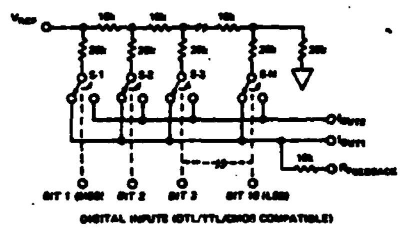
CMOS Low Cost 10-Bit Multiplying DAC

AD7533

FEATURES
- Lowest Cost 10-Bit DAC
- Low Cost AD7520 Replacement
- Linearity: 1/2, 1 or 2LSB
- Low Power Dissipation
- Full Four-Quadrant Multiplying DAC
- CMOS/TTL Direct Interface
- Latch Free (Protection Schottky not Required)
- End-Point Linearity

APPLICATIONS
- Digitally Controlled Attenuators
- Programmable Gain Amplifiers
- Function Generation
- Linear Automatic Gain Control

AD7533 FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION
The AD7533 is a low cost 10-bit 4-quadrant multiplying DAC manufactured using an advanced thin-film-on-monolithic-CMOS wafer fabrication process.

Pin and function equivalent to the industry standard AD7520, *the AD7533 is recommended as a lower cost alternative for* old AD7520 sockets or new 10-bit DAC designs.

AD7533 application flexibility is demonstrated by its ability to interface to TTL or CMOS, operate on +5V to +15V power, and provide proper binary scaling for reference inputs of either positive or negative polarity.

PACKAGE IDENTIFICATION[1]
Suffix D: Ceramic DIP – (D16B)
Suffix N: Plastic DIP – (N16B)

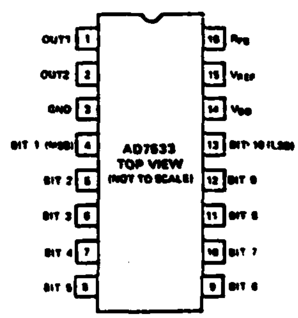
[1] See Section 20 for package outline information.

ORDERING INFORMATION

Nonlinearity	Temperature Range		
	Commercial 0 to +70°C	Industrial -25°C to +85°C	Military -55°C to +125°C
±0.2%	AD7533JN	AD7533AD AD7533AD/883B[1]	AD7533SD AD7533SD/883B[1]
±0.1%	AD7533KN	AD7533BD AD7533BD/883B[1]	AD7533TD AD7533TD/883B[1]
±0.05%	AD7533LN	AD7533CD AD7533CD/883B[1]	AD7533UD AD7533UD/883B[1]

[1] 100% screened to MIL-STD-883, method 5004, para. 3.1.1 through 3.1.12 for Class B device.

PIN CONFIGURATION



10

SPECIFICATIONS (V_{DD} = +15V; V_{OUT1} = V_{OUT2} = 0V; V_{REF} = +10V unless otherwise noted)

PARAMETER	T_A = 25°C	T_A = Operating Range[1]	Test Conditions
STATIC ACCURACY			
Resolution	10 Bits	10 Bits	
Relative Accuracy[2,3]			
AD7533JN, AD, SD	±0.2% FSR max	±0.2% FSR max	
AD7533KN, BD, TD	±0.1% FSR max	±0.1% FSR max	
AD7533LN, CD, UD	±0.05% FSR max	±0.05% FSR max	
Gain Error[3,4,5]	±1.4% FS max	±1.5% FS max	Digital Inputs = V_{INH}
Supply Rejection[6]			
$\Delta Gain/\Delta V_{DD}$	0.005%/%	0.008%/%	Digital Inputs = V_{INH}; V_{DD} = +14V to -:
Output Leakage Current			
I_{OUT1} (pin 1)	±50nA max	±200nA max	Digital Inputs = V_{INL}; V_{REF} = ±10V
I_{OUT2} (pin 2)	±50nA max	±200nA max	Digital Inputs = V_{INH}; V_{REF} = ±10V
DYNAMIC ACCURACY			
Output Current Settling Time	600ns max[7]	800ns[6]	To 0.05% FSR; R_{LOAD} = 100Ω; Digital Inputs = V_{INH} to V_{INL} or V_{INL} to V_{INH}
Feedthrough Error	±0.05% FSR max[6]	±0.1% FSR max[6]	Digital Inputs = V_{INL}; V_{REF} = ±10V, 100kHz sinewave.
REFERENCE INPUT			
Input Resistance (pin 15)	5kΩ min, 20kΩ max	5kΩ min, 20kΩ max[8]	
ANALOG OUTPUTS			
Output Capacitance			
C_{OUT1} (pin 1)	100pF max[6]	100pF max[6]	Digital Inputs = V_{INH}
C_{OUT2} (pin 2)	35pF max[6]	35pF max[6]	Digital Inputs = V_{INH}
C_{OUT1} (pin 1)	35pF max[6]	35pF max[6]	Digital Inputs = V_{INL}
C_{OUT2} (pin 2)	100pF max[6]	100pF max[6]	Digital Inputs = V_{INL}
DIGITAL INPUTS			
Input High Voltage			
V_{INH}[3]	2.4V min	2.4V min	
Input Low Voltage			
V_{INL}[3]	0.8V max	0.8V max	
Input Leakage Current			
I_{IN}[3]	±1μA max	±1μA max	V_{IN} = 0V and V_{DD}
Input Capacitance			
C_{IN}	5pF max[6]	5pF max[6]	
POWER REQUIREMENTS			
V_{DD}	+15V ±10%	+15V ±10%	Rated Accuracy
V_{DD} Range[6]	+5V to +16V	+5V to +16V	Functionality with degraded performance
I_{DD}[3]	2mA max	2mA max	Digital Inputs = V_{INL} or V_{INH}

NOTES:

[1] Plastic (JN, KN, LN versions): 0 to +70°C
Commercial Ceramic (AD, BD, CD versions): -25°C to +85°C
Military Ceramic (SD, TD, UD versions): -55°C to +125°C

[2] "FSR" is Full Scale Range.

[3] Final electrical tests are: Relative Accuracy, Gain Error, Output Leakage Current, V_{INH}, V_{INL}, I_{IN} and I_{DD} at +25°C and +125°C (SD, TD, UD versions) or +25°C and +85°C (AD, BD, CD versions).

[4] Full Scale (FS) = $-(V_{REF})\left(\frac{1023}{1024}\right)$

[5] Max gain change from T_A = +25°C to T_{min} or T_{max} is ±0.1% FSR.

[6] Guaranteed, not tested.

[7] AC parameter, sample tested to ensure specification compliance.

[8] Absolute temperature coefficient is approximately -300ppm/°C.

Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS
(T_A = +25°C unless otherwise noted)

V_{DD} to GND . . . . -0.3V, +17V
R_{FB} to GND . . . . ±25V
V_{REF} to GND. . . . . ±25V
Digital Input Voltage Range . . . . -0.3V to V_{DD}
Output Voltage (pin 1, pin 2) . . . . -0.3V to V_{DD}
Power Dissipation (Package)
Plastic (Suffix N)
To +70°C. 670mW
Derates above +70°C by . . . . 8.3mW/°C
Ceramic (Suffix D)
To +70°C. 450mW
Derates above +75°C by . . . . 6mW/°C
Operating Temperature Range
Commercial (JN, KN, LN versions). . . . . 0 to +70°C
Industrial (AD, BD, CD versions) . . . . -25°C to +85°C
Military (SD, TD, UD versions) . . . . -55°C to +125°C
Storage Temperature . . . . -65°C to +150°C
Lead Temperature (Soldering, 10 seconds). . . . . +300°C

CAUTION:

1. ESD sensitive device. The digital control inputs are Zener protected; however, permanent damage may occur on unconnected devices subjected to high energy electrostatic fields. Unused devices must be stored in conductive foam or shunts.
2. Do not apply voltages lower than ground or higher than V_{DD} to any pin except V_{REF} (pin 15) and R_{FB} (pin 16).

TERMINOLOGY

RELATIVE ACCURACY: Relative accuracy or end-point nonlinearity is a measure of the maximum deviation from a straight line passing through the endpoints of the DAC transfer function. It is measured after adjusting for ideal zero and full scale and is expressed in % or ppm of full-scale range or (sub) multiples of 1LSB.

RESOLUTION: Value of the LSB. For example, a unipolar converter with n bits has a resolution of (2^{-n}) (V_{REF}). A bipolar converter of n bits has a resolution of $[2^{-(n-1)}]$ $[V_{REF}]$. Resolution in no way implies linearity.

SETTLING TIME: Time required for the output function of the DAC to settle to within 1/2 LSB for a given digital input stimulus, i.e., 0 to Full Scale.

GAIN ERROR: Gain error or full-scale error is a measure of the output error between an ideal DAC and the actual device output.

FEEDTHROUGH ERROR: Error caused by capacitive coupling from V_{REF} to output with all switches OFF.

OUTPUT CAPACITANCE: Capacity from I_{OUT1} and I_{OUT2} terminals to ground.

OUTPUT LEAKAGE CURRENT: Current which appears on I_{OUT1} terminal with all digital inputs LOW or on I_{OUT2} terminal when all inputs are HIGH.

CIRCUIT DESCRIPTION

GENERAL CIRCUIT INFORMATION

The AD7533, a 10-bit multiplying D/A converter, consists of a highly stable thin film R-2R ladder and ten CMOS current switches on a monolithic chip. Most applications require the addition of only an output operational amplifier and a voltage or current reference.

The simplified D/A circuit is shown in Figure 1. An inverted R-2R ladder structure is used – that is, the binarily weighted currents are switched between the I_{OUT1} and I_{OUT2} bus lines, thus maintaining a constant current in each ladder leg independent of the switch state.

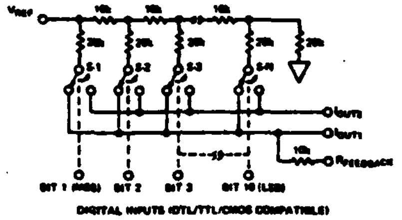


Figure 1. AD7533 Functional Diagram

One of the CMOS current switches is shown in Figure 2. The geometries of devices 1, 2 and 3 are optimized to make the digital control inputs DTL/TTL/CMOS compatible over the full military temperature range. The input stage drives two inverters (devices 4, 5, 6 and 7) which in turn drive the two output N-channels. The "ON" resistances of the switches are binarily sealed so the voltage drop across each switch is the same. For example, switch 1 of Figure 2 was designed for an "ON" resistance of 20 ohms, switch 2 for 40 ohms and so on. For a 10V reference input, the current through switch 1 is 0.5mA, the current through switch 2 is 0.25mA, and so on, thus maintaining a constant 10mV drop across each switch. It is essential that each switch voltage drop be equal if the binarily weighted current division property of the ladder is to be maintained.

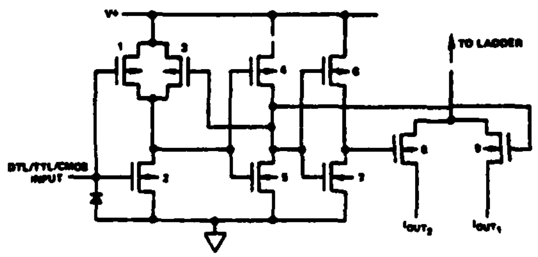


Figure 2. CMOS Switch

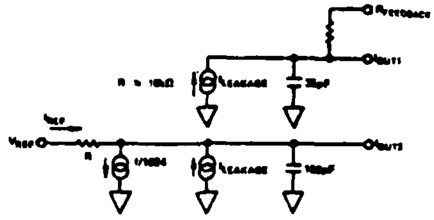


Figure 3. AD7533 Equivalent Circuit – All Digital Inputs Lo

EQUIVALENT CIRCUIT ANALYSIS

The equivalent circuits for all digital inputs high and all digi inputs low are shown in Figures 3 and 4. In Figure 3 with all digital inputs low, the reference current is switched to I_{OUT2}. The current source $I_{LEAKAGE}$ is composed of surface and junction leakages to the substrate while the $\frac{I}{1024}$ current source represents a constant 1-bit current drain through the termination resistor on the R-2R ladder. The "ON" capacitance of the output N channel switch is 100pF, as shown on the I_{OUT2} terminal. The "OFF" switch capacitance is 35pF, as shown on the I_{OUT1} terminal. Analysis of the circuit for all digital inputs high, as shown in Figure 4, is similar to Figure 3, however, the "ON" switches are now on terminal I_{OUT1}, hence the 100pF at that terminal.

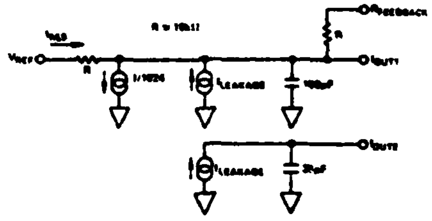


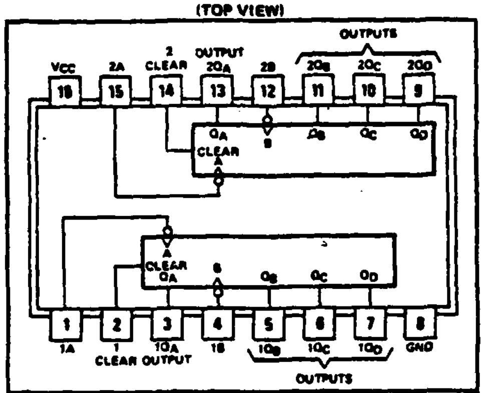
Figure 4. AD7533 Equivalent Circuit – All Digital Inputs High

TYPES SN54390, SN54LS390, SN54393, SN54LS393, SN74390, SN74LS390, SN74393, SN74LS393 DUAL 4-BIT DECADE AND BINARY COUNTERS

BULLETIN NO. DL-S 7612099, OCTOBER 1976

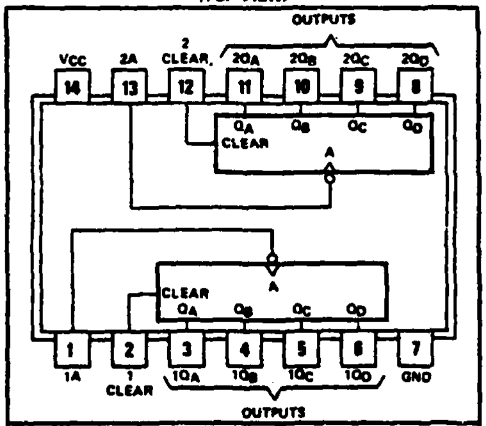
- Dual Versions of the Popular '90A, 'LS90 and '93A, 'LS93
- '390, 'LS390. . .Individual Clocks for A and B Flip-Flops Provide Dual ÷2 and ÷5 Counters
- '393, 'LS393. . .Dual 4-Bit Binary Counter with Individual Clocks
- All Have Direct Clear for Each 4-Bit Counter
- Dual 4-Bit Versions Can Significantly Improve System Densities by Reducing Counter Package Count by 50%
- Typical Maximum Count Frequency . . . 35 MHz
- Buffered Outputs Reduce Possibility of Collector Commutation

SN54390, SN54LS390 . . . J OR W PACKAGE
SN74390, SN74LS390 . . . J OR N PACKAGE
(TOP VIEW)



positive logic: High input to clear resets all four outputs low

SN54393, SN54LS393 . . . J OR W PACKAGE
SN74393, SN54LS393 . . . J OR N PACKAGE
(TOP VIEW)



positive logic: High input to clear resets all four outputs low

description

Each of these monolithic circuits contains eight master-slave flip-flops and additional gating to implement two individual four-bit counters in a single package. The '390 and 'LS390 incorporate dual divide-by-two and divide-by-five counters, which can be used to implement cycle lengths equal to any whole and/or cumulative multiples of 2 and/or 5 up to divide-by-100. When connected as a bi-quinary counter, the separate divide-by-two circuit can be used to provide symmetry (a square wave) at the final output stage. The '393 and 'LS393 each comprise two independent four-bit binary counters each having a clear and a clock input. N-bit binary counters can be implemented with each package providing the capability of divide-by-256. The '390, 'LS390, '393, and 'LS393 have parallel outputs from each counter stage so that any submultiple of the input count frequency is available for system-timing signals.

Series 54 and Series 54LS circuits are characterized for operation over the full military temperature range of −55°C to 125°C; Series 74 and Series 74LS circuits are characterized for operation from 0°C to 70°C.

TYPES SN54390, SN54LS390, SN54393, SN54LS393, SN74390, SN74LS390, SN74393, SN74LS393 DUAL 4-BIT DECADE AND BINARY COUNTERS

FUNCTION TABLES

'390, 'LS390
BCD COUNT SEQUENCE
(EACH COUNTER)
(See Note A)

COUNT	OUTPUT			
	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H

'390, 'LS390
BI-QUINARY (5-2)
(EACH COUNTER)
(See Note B)

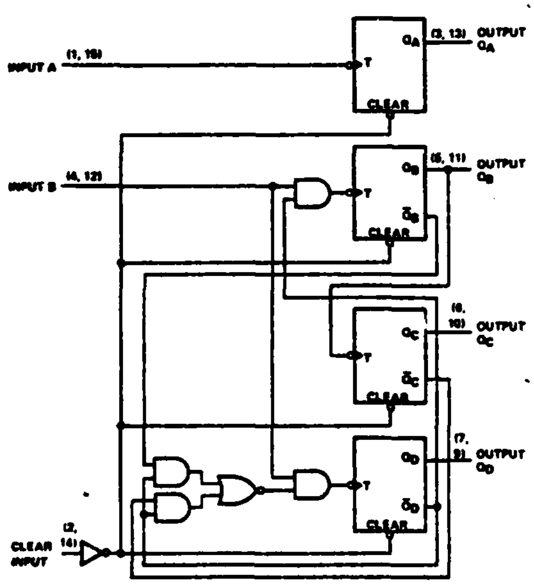
COUNT	OUTPUT			
	Q_A	Q_D	Q_C	Q_B
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	H	L	L	L
6	H	L	L	H
7	H	L	H	L
8	H	L	H	H
9	H	H	L	L

'393, 'LS393
COUNT SEQUENCE
(EACH COUNTER)

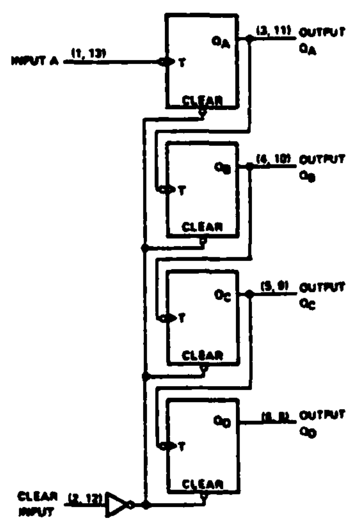
COUNT	OUTPUT			
	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H
10	H	L	H	L
11	H	L	H	H
12	H	H	L	L
13	H	H	L	H
14	H	H	H	L
15	H	H	H	H

NOTES: A. Output Q_A is connected to input B for BCD count.
B. Output Q_D is connected to input A for bi-quinary count.
C. H = high level, L = low level.

functional block diagrams



'390, 'LS390

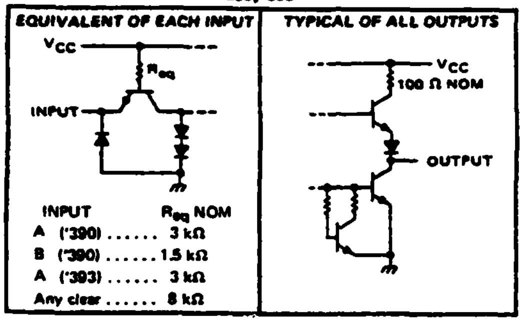


'393, 'LS393

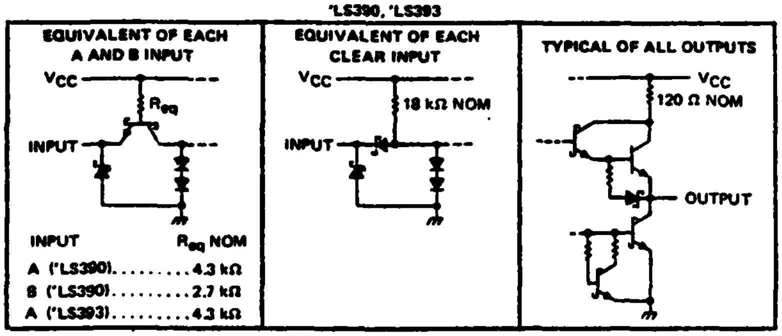
TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 5012 • DALLAS, TEXAS 75222

schematics of inputs and outputs

'390, '393



'LS390, 'LS393



APPENDIX B

F8 MICROPROCESSOR SOFTWARE

This appendix contains the source codes for the F8 developed in conjunction with the design of the Automatic Threshold Control for the scanner. Assembly listings and linking information for each software module are included. The floppy disc HELP file describing the software package is also included to serve as an overview.

THIS IS THE MAIN DESCRIPTOR FILE FOR THIS DISK.
IT DESCRIBES THE PROGRAMS ON IT AND HOW TO USE THEM.

PROGRAMS MODIFIED AND DEBUGGED
BY
CAPT B. J. STANTON, JUNE 82.

***** USER INFORMATION *****

THE F8 PROVIDES THRESHOLD AND PRINTER CONTROL FOR THE ELECTRO-OPTICAL PAGE SCANNER (EOPS). THE SOFTWARE IS IN A VARIETY OF FORMS DESIGNATED BY THE FILE ATTRIBUTE:

'00' IS A TEXT FILE SUCH AS THIS ONE OR ONE CONTAINING UNASSEMBLED SOURCE CODE.

'10' IS AN OBJECT CODE FILE THAT CAN BE LOADED AND/OR LINKED, DEPENDING ON THE NATURE OF THE SOFTWARE.

'30' IS A CORE IMAGE FILE THAT (WHEN LOCATED ON DISK DRIVE 0) IS LOADED AND EXECUTED AS A SYSTEM-LEVEL COMMAND WHEN THE FILENAME IS ENTERED.

'40' IS AN EXECUTIVE FILE FOR FACILITATING VARIOUS FILE OPERATIONS.

THE FILES EOPS1,30:1 AND EOPS2,30:1 ARE COMPLETE SOFTWARE PACKAGES. EOPS1 AND EOPS2 ARE DISTINGUISHED BY THEIR THRESHOLD SAMPLING ALGORITHMS. EOPS1 HAS AN INITIAL STEP SIZE (S1) OF 128 AND SAMPLES THE ENTIRE RANGE OF N (0 TO 1024). EOPS2 HAS AN INITIAL STEP SIZE OF 64 AND SAMPLES THE RANG OF N (128 TO 640). TO USE EITHER OF THESE PACKAGES, FIRST INSURE THE DESIRED PACKAGE IS LOADED ONTO DISK DRIVE 0. YOU MAY WANT TO MAKE A COPY OF ONE OF THESE FILES ON DRIVE 0 BY EXECUTING A COMMAND SUCH AS:

COPY FILE E0PS1,30:1

TO PUT THE F8 INTO THE EOPS MODE, CALL THE APPROPRIATE SOFTWARE PACKAGE BY TYPING ITS NAME:

EOPS1

ONCE THE SOFTWARE IS LOADED AND RUNNING, USER CONTROL IS PROVIDED THROUGH THE 'SENSE' SWITCHES ON THE FRONT PANEL OF THE F8. THE FUNCTIONS ARE:

SENSE #	DOWN	UP
4	NORMAL OPERATION	RETURN TO DOS4
5	NORMAL PAGE	INFINITE LINES
6	AUTOMATIC THRESHOLD	THRESHOLD FREEZE
7	SOFT COPY	HARD COPY

SENSE 4 IS USED TO EXIT EOPS MODE AND RETURN CONTROL OF THE F8 TO THE ZENITH KEYBOARD. (CAUTION: THIS SWITCH MUST BE DOWN WHEN ENTERING EOPS; OTHERWISE AN IMMEDIATE JUMP BACK TO THE OPERATING SYSTEM WILL OCCUR.

SENSE 5 IS USED FOR CALIBRATION AND CAUSES THE LINE COUNTER TO BE DISABLED SO THAT, WITH THE SCANNER IN 'FREEZE MODE' THE SOFTWARE WILL CONTINUE TO ACCEPT AN INFINITE STREAM OF LINES WITHOUT ENDING THE PAGE. WHEN SENSE 5 IS RETURNED TO TO THE DOWN POSITION THE SOFTWARE IMMEDIATELY EXECUTES THE END OF PAGE SEQUENCE AND RESETS.

SENSE 6 IS USED FOR CONTROL OF THE AUTOMATIC THRESHOLD FEATURE. IN AUTOMATIC THRESHOLD MODE, 28 LINES OF THE LEADING MARGIN CONTAINING THE TEST PATTERN ARE SAMPLED TO OBTAIN THE OPTIMUM THRESHOLD FOR EXISTING CONDITIONS. THE VALUE OF THE SELECTED THRESHOLD IS DISPLAYED ON THE SCREEN IN HEX. IN THRESHOLD FREEZE MODES, THE LAST THRESHOLD SET BY THE SOFTWARE IS RETAINED AND DISPLAYED ON THE SCREEN. NOTE: IF THE THRESHOLD IS ALTERED FROM THE FRONT PANEL OR BY OTHER DEBUGGING MEANS, THE MESSAGE TO THE SCREEN WILL NOT REFLECT THE ALTERATION.

SENSE 7 SELF EXPLANATORY.

EOPS IS IN TURN COMPOSED OF SMALLER LINKABLE SOFTWARE PACKAGES. THESE MODULES ARE DESCRIBED BELOW:

MAIN4 ------ MAIN CALLING PROGRAM, VERSION 4

THIS MODULE CONTAINS THE MAINLINE ROUTINES OF EOPS AND THEREFORE MUST BE AT THE BEGINNING LINK. IT CONTAINS ALL INITIALIZATIONS, SENSE SWITCH CONTROLS, LINE COUNTERS, COMMAND TRANSMISSIONS, CRT SCREEN PROMPTS, AND ATC CALLS. IT ALSO INITIALIZES THE SAMPLING ALGORITHM, QSET, THEREBY CONTROLLING SAMPLING RANGE AND INITIAL STEP SIZE (31).

FSTLN ----- FIRST LINE

THIS SUBROUTINE POLLS THE SIGNAL CALLED 'PRINTLINE' WHICH IS PRESENT ON INPUT PORT 4 IN THE LEAST SIGNIFICANT BIT POSITION. THE PROGRAM IS DESIGNED TO DETECT A RISING TRANSITION OF THE INPUT SIGNAL. THIS IS ACCOMPLISHED BY LOOPING UNTIL THE SIGNAL IS FALSE AND THEN LOOPING UNTIL IT IS TRUE. WHEN THIS PROGRAM RETURNS, THE TRANSITION WILL HAVE JUST OCCURRED. THE SOFTWARE IS DESIGNED TO TAKE INTO ACCOUNT THE INVERSION THAT TAKES PLACE THROUGH THE F8 I/O PORT. THEREFORE THIS MODULE ACTUALLY SENSES A DOWNWARD TRANSITION OF THE SIGNAL 'PRINTLINE' IN THE SCANNER. THE GOAL IS TO CATCH THIS DOWNWARD TRANSITION WHICH SIGNALS THE END OF A LINE OF VIDEO INFORMATION.

ENDLN ----- END OF LINE

THIS SUBROUTINE IS A SLIGHTLY MORE COMPLEX VERSION OF FSTLN. IT ALSO DETECTS A FALLING TRANSITION OF 'PRINTLINE' HOWEVER, IT IS DESIGNED TO WAIT FOR THIS TRANSISTION FOR 10 MS. THIS FEATURE WAS INCLUDED TO PREVENT THE SOFTWARE FROM GETTING HUNG UP AND OUT OF SYNC IF THE SCANNER SHOULD EITHER STOP IN MIDPAGE OR PRODUCE A FALSE START. IN THE EVENT THAT THIS SUBROUTINE MUST WAIT MORE THAN 10 MS, IT SETS THE LINE COUNTER TO THE LAST LINE SO THAT WHEN THE RETURN TO THE MAIN PROGRAM OCCURS, THE LAST LINE CONDITION WILL BE INVOKED AND THE SOFTWARE WILL RESET. SHOULD IT BE NECESSARY TO HAVE THE SCANNER FROZEN IN MIDPAGE AND STILL HAVE THE SOFTWARE OPERATING SYNCRONOUSLY WITH THE SCANNER (FOR ALIGNMENT ETC.), SENSE SWITCH 5 SHOULD BE USED.

XMITS ----- TRANSMIT COMMAND

THIS IS THE SIMPLEST OF ALL THE SUBROUTINES. IT IS THE ONE WHICH ACTUALLY SENDS THE COMMANDS TO THE PRINTER OR THE TEKTRONICS DISPLAY. IT EXPECTS THE COMMAND CHANNEL IN THE INTERFACE BOARD TO HAVE ALREADY BEEN OPENED AND THE COMMAND FOR TRANSMISSION TO BE STORED IN REGISTER 9.

QSET ----- QUICK THRESHOLD SAMPLING ALGORITHM

THIS MODULE SAMPLES THE RANGE OF THRESHOLD VALUES BY USING PROGRESSIVELY SMALLER AND SMALLER STEP SIZES. EACH TIME QSET IS CALLED, THE EXISTING STEP SIZE WILL BE USED FOR SEVEN SAMPLES AND WILL THEN BE DIVIDED BY FOUR BEFORE CONTROL IS RETURNED TO THE MAIN CALLING PROGRAM. WITH EACH VALUE OF N, VTC IS COMPARED TO THE PREVIOUS MAXIMUM VTC (MTC). THE VALUE OF N PRODUCING THE OVERALL MAXIMUM VALUE OF VTC IS STORED FOR EITHER THE NEXT INVOCATION OF QSET OR FOR THE MAIN CALLING PROGRAM TO LOAD INTO PORTS 12 AND 13 AS THE OPTIMUM THRESHOLD VALUE FOR THE PAGE TO BE SCANNED.

********************** EXAMPLES **************************

SHOULD IT BE NECESSARY TO REASSEMBLE AND RELINK THE LOPS SOFTWARE PACKAGE, THE FOLLOWING SEQUENCE OF COMMANDS WILL PRODUCE THIS RESULT:

```
ASM MAIN4,00:1 TO MAIN4,10:1 NOLIST ERRS
ASM FSTLN,00:1 TO FSTLN,10:1 NOLIST ERRS
ASM ENDLN,00:1 TO ENDLN,10:1 NOLIST ERRS
ASM XMITS,00:1 TO XMITS,10:1 NOLIST ERRS
ASM QSET ,00:1 TO QSET ,10:1 NOLIST ERRS

LINK 1 CLEAR ORG 0 MAIN4,10:1
LINK 1 FSTLN,10:1
LINK 1 ENDLN,10:1
LINK 1 XMITS,10:1
LINK 1 QSET ,10:1
```

THE SOFTWARE IS NOW LOADED IN RAM AND READY FOR EXECUTION EITHER FROM THE FRONT PANEL OR BY USING THE F8 DEBUG SOFTWARE. SHOULD IT BE NECESSARY TO CREATE A FILE FROM THE ABOVE MODULES THAT CAN BE LOADED WITH A SINGLE COMMAND, THE FOLLOWING COMMANDS CAN BE USED:

```
ASS DO VDISK FILENAME.10:1
DUMP 0000-0255
```

THIS PACKAGE WILL BE STORED ON DISK, AND CAN BE LOADED INTO RAM AT ANY TIME BY THE COMMAND:

```
LOAD FILENAME,10:1
```

TO EXECUTE THE PROGRAM LOADED IN THIS MANNER, USE THE F8 FRONT PANEL:

```
HALT
```

CLEAR DISPLAY
LD ADDRESS
RUN

IF THE USER WISHES TO HAVE A FILE WHICH LOADS AND ALSO AUTOMATICALLY EXECUTES FROM THE SYSTEM DISK, IN PLACE OF THE ABOVE EXAMPLE, THESE FOLLOWING COMMANDS CAN BE EXECUTED:

CCI FILENAME,30:1 0000-0255
COPY FILE FILENAME,30:1

THIS LAST COMMAND PLACES A COPY OF THE CORE IMAGE ON THE SYSTEM DISK WHERE IS WILL BE FOUND BY THE OPERATING SYSTEM IN RESPONSE TO THE USER TYPING 'FILENAME', SINCE THE SYSTEM LOOKS FOR LOAD-AND-EXECUTE FILES ON DRIVE 0 WHERE THE SYSTEM DISK USUALLY RESIDES.

IT MUST BE NOTED THAT THESE COMMANDS TO CREATE NEW COPIES OF THE OPERATING PROGRAMS MUST BE EXECUTED IMMEDIATELY FOLLOWING THE LINKING OPERATION SINCE SOME OF THE OTHER FDOS PROGRAMS (LIKE THE ASSEMBLER AND THE EDITOR) OBSCURE THE LOWER ADDRESSES OF THE MEMORY WHERE THE SCANNER PROGRAMS ARE LOADED.

ON THIS DISK THE FILES EOPS1,30:1 AND EOPS2,30:1 ARE AUTOMATIC LOAD-AND-EXECUTE FILES WHICH CAN BE COPIED TO A DISK IN DRIVE 0 FOR IMMEDIATE USE.

FOR FURTHER INFORMATION CONCERNING THE OPERATION OF THE F8 AND ITS OPERATING SYSTEM FDOS, CONSULT THE USERS MANUALS SUPPLIED WITH THE SYSTEM.

```
MAIN CALLING PROGRAM-VERSN 4
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

                  0000      MAIN4    RORG   0
                            *
                                     TITLE 'MAIN CALLING PROGRAM-VERSN 4'
                            *
                            * WRITTEN BY CAPT B. J. STANTON, 21 JUN 82
                            * EDITED 21 JULY 82.
                            * THIS IS THE MAIN CALLING PROGRAM FOR THE
                            * ELECTRO-OPTICAL PAGE SCANNER.  IT MUST BE
                            * LINKED FIRST WHEN BUILDING THE SOFTWARE
                            * PACKAGE 'EOPS-'
                            *
                            * THE USE OF THE FS FRONT PANEL SENSE SWTCHS:
                            *
                            * #       DOWN                      UP
                            *-----------------------------------------
                            * 4   NORMAL OPERATION       RETURN TO DOS4
                            * 5   NORMAL PAGE            INFINITE LINES
                            * 6   AUTOMATIC THRESHOLD    THRESHOLD FREEZE
                            * 7   SOFT COPY              HARD COPY
                            *-----------------------------------------
                            *
                            *
                  2330      DOS4     EQU   H'2330'
                  0006      LINEU    EQU   6           LINE CNTR HIGH BYTE
                  00A4      LINEL    EQU   164         LINE CNTR LOW BYTE
                            *
                            * CODES FOR PORT 8
                            *
                  0000      ENCMD    EQU   H'00'       CODE FOR CMD CHANNEL
                  0020      ENCCD    EQU   H'20'       CCD CHANNEL CMS
                  0040      ENSENS   EQU   H'40'       CONN INP SW TO PRT4
                            *
                            * DEVICE ADDRESSES (FOR PORT 8)
                            *
                  0001      ADHARD   EQU   H'01'       ADDRESS OF PRINTER
                  0008      ADSOFT   EQU   H'08'       ADDR OF TEK. DISPL
                            *
                            * CODES FOR PORT 9
                            *
                  0009      LDADDR   EQU   H'09'       ADDR LOAD CODE
                            *
                            * DEVICE COMMANDS SENT THRU PORT 8, AND
                            * CONTROLLED BY PORT 9
                            *
                  000B      HARDLMJ  EQU   H'0B'       LEFT MARG JUSTIFY
                  0000      HARDFIL  EQU   H'00'       FILL,PRT LINE BUFF
                  0003      HARDADV  EQU   H'03'       ADVANCE ONE LINE
                  000F      HARDCUT  EQU   H'0F'       CUT PAPER
                  0037      HARDOFF  EQU   H'37'       SHUT OFF PTR (PUMPS)
                  0006      SOFTEN   EQU   H'06'       ENBLE SOFTCOPY DISPL
                  0003      SOFTDSB  EQU   H'03'       DSBL SOFTCOPY DISPL
                  0001      SOFTERS  EQU   H'01'       ERASE SOFTCOPY DISPL
                  0002      SOFTRSY  EQU   H'02'       RESET Y COUNTER
                  0004      SOFTINY  EQU   H'04'       INCREMENT Y COUNTER
                            *
                            *
                            * LINKING INFO
                                     EXTRN ENDLN,FSTLN,WHITS,RSET
                            *
                            *
                            *
```

```
MAIN CALLING PROGRAM-VERSN 4
ERRS  LOC OBJECT ADDR LINE            SOURCE STATEMENT

      0000 1A                            DI              DISABLE INTERRUPTS
      0001 71                            LIS   1         RESET INTERFACE
      0002 B9                            OUTS  9
      0003 70                            CLR
      0004 B9                            OUTS  9
      0005 2000                OVER      LI    ENCMD     SET FOR CMD XMIT
                               *
                               *---------------------DATA CHANNEL CLOSED
                               *
      0007 B5                            OUTS  5
                               *
      0008 2040                BEGIN     LI    ENSENS    ENABLE SCANNER INPUT
      000A B5                            OUTS  5
      000B 70                            CLR             LOOP TILL
      000C B4                            OUTS  4         INIT = 0
      000D A4                            INS   4
      000E 2102                          NI    H'02'     INIT = BIT 2
      0010 94F7     0008                 BNZ   BEGIN
                               *
      0012 70                  BEGIN2    CLR             TEST FOR QUIT SIG
      0013 B0                            OUTS  0         ON F8 SENSE 4
      0014 A0                            INS   0
      0015 2110                          NI    H'10'
      0017 8404     001C                 BZ    SKIPM
      0019 292330   2330                 JMP   DOS4      RETURN TO DOS
                               *
      001C 70                  SKIPM     CLR             LOOP TILL
      001D B4                            OUTS  4         INIT = 1
      001E A4                            INS   4
      001F 2102                          NI    H'02'     INIT = BIT 2
      0021 84F0     0012                 BZ    BEGIN2
                               *
                               *****DELAY LOOP*****
                               *
      0023 70                            CLR             WAIT 2.3 MS
      0024 1F                  DLI       INC
      0025 94FE     0024                 BNZ   DLI
                               *
                               *****END DELAY******
                               *
      0027 70                            CLR             CHECK START AGAIN
      0028 B4                            OUTS  4
      0029 A4                            INS   4
      002A 2102                          NI    H'02'
      002C 84E5     0012                 BZ    BEGIN2
                               *
      002E 70                            CLR             GET F8 SENSE 7
      002F B0                            OUTS  0         FOR HARD/SOFT OUTPUT
      0030 A0                            INS   0
      0031 2180                          NI    H'80'
      0033 58                            LR    8,A
                               *
      0034 48                            LR    A,8       USE REGS FOR HDR/SFT
      0035 2500                          CI    H'00'
      0037 8411     0049                 BZ    SOFT
                               *
      0039 2001                HARD      LI    ADHARD    SETUP FOR PRINTER
      003B B8                            OUTS  8
      003C 2008                          LI    LDADDR    STORE PRINTER ADDR
      003E B9                            OUTS  9
      003F 70                            CLR
```

```
MAIN CALLING PROGRAM-VERSN 4
ERRS  LOC OBJECT ADDR LINE           SOURCE STATEMENT

      0040 B9             0123              OUTS  9
      0041 2003           0124              LI    HARDLMU    START PUMPS IN PRTR
      0043 59             0125              LR    9,A
      0044 280000 0000    0126              PI    XMITS
      0047 9015   005D    0127              BR    SKIP1
                          0128   *
      0049 2005           0129   SOFT       LI    ADSOFT     SETUP FOR TEK-DISPL
      004B 38             0130              OUTS  8
      004C 2008           0131              LI    LDADDR     STORE TEK ADDR
      004E B9             0132              OUTS  9
      004F 70             0133              CLR
      0050 B9             0134              OUTS  9
      0051 2002           0135              LI    SOFTRSY    INITIALIZE TEK-DISPL
      0053 59             0136              LR    9,A
      0054 280000 0000    0137              PI    XMITS
      0057 2001           0138              LI    SOFTERS    ERASE SCREEN
      0059 59             0139              LR    9,A
      005A 280000 0000    0140              PI    XMITS
                          0141   *
                          0142   *****DELAY LOOPS*****************
                          0143   *
      005D 20FA           0144   SKIP1      LI    D'250'     DELAY FOR PUMPS OR
      005F 52             0145              LR    2,A          SCREEN ERASE
      0060 20C8           0146   LOOP0      LI    D'200'
      0062 53             0147              LR    3,A
      0063 33             0148   LOOP1      DS    3
      0064 94FE   0063    0149              BNZ   LOOP1
      0066 32             0150              DS    2
      0067 94F8   0060    0151              BNZ   LOOP0
                          0152   *
                          0153   *****END DELAY***************
                          0154   *
      0069 280000 0000    0155              PI    FSTLN      WAIT FOR FIRST LINE
                          0156   *
                          0157   * CHECK FOR AUTO THRESHOLD DISABLE----------
                          0158   *
      006C 70             0159              CLR
      006D B0             0160              OUTS  0
      006E A0             0161              INS   0
      006F 2140           0162              NI    H'40'
      0071 9455   00C7    0163              BNZ   FPZ
                          0164   *
                          0165   *****
                          0166   * BEGIN AUTOMATIC THRESHOLD SETTING SEQUENCE
                          0167   *****
      0073 70             0168              CLR              MAX DIGITAL VIDEO
      0074 56             0169              LR    6,A        (MTC) INITIALIZED
      0075 57             0170              LR    7,A        TO ZERO
                          0171   *
                          0172   *  INITIALIZE FOR THRESHOLD SAMPLING---------
                          0173   *
                          0174   ***************      NOTE!!!    ***************
                          0175   *
                          0176   *  AS IT STANDS NOW, DSET IS INITIALIZED TO
                          0177   *  SAMPLE THE RANGE 128 TO 640 WITH AN
                          0178   *  INITIAL STEP SIZE OF 64 AS DOCUMENTED FOR
                          0179   *  THE SOFTWARE PACKAGE, 'EOPS2'.
                          0180   *
                          0181   *  TO SAMPLE THE ENTIRE RANGE OF N (0 TO 1024)
                          0182   *  SCRATCH REGISTER 5 MUST BE LOADED WITH ZERO
                          0183   *  AND SCRATCH REGISTER 3 MUST BE LOADED WITH
```

```
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT
                      0184  *  128.
                      0185  *
                      0186  ******************************************
                      0187  *
                      0188  *
      0076 54         0189          LR    4,A       THRESHOLD SET TO
      0077 2080       0190          LI    128       START AT 128
      0079 55         0191          LR    5,A
      007A 2040       0192          LI    64        STEP SIZE INITIALIZE
      007C 53         0193          LR    3,A       TO 64
                      0194  *
                      0195  * TAKE FOUR PASSES (AT 7 LINES PER PASS)-----
                      0196  *
      007D 280000 0000 0197         PI    QSET
      0080 280000 0000 0198         PI    QSET
      0083 280000 0000 0199         PI    QSET
      0086 280000 0000 0200         PI    QSET
                      0201  *
                      0202  * LOAD OPTIMUM THRESHOLD--------------------
                      0203  *
      0089 02         0204          LR    A,QU
      008A 2713       0205          OUT   H'13'
      008C 03         0206          LR    A,QL
      008D 2712       0207          OUT   H'12'
                      0208  *
                      0209  * DISPLAY OPTIMUM THRESHOLD-----------------
                      0210  *
      008F 2A017E 017E 0211 SHOW    DCI   MSG1+21
      0092 2C         0212          XDC
      0093 2A0197 0197 0213         DCI   MSG2+22
      0096 02         0214          LR    A,QU
      0097 2430       0215          AI    H'30'
      0099 2539       0216          CI    H'39'
      009B 8103   009F 0217         BP    SH1
      009D 2407       0218          AI    H'07'
      009F 17         0219 SH1      ST
      00A0 2C         0220          XDC
      00A1 17         0221          ST
      00A2 03         0222          LR    A,QL
      00A3 14         0223          SR    4
      00A4 2430       0224          AI    H'30'
      00A6 2539       0225          CI    H'39'
      00A8 8103   00AC 0226         BP    SH2
      00AA 2407       0227          AI    H'07'
      00AC 17         0228 SH2      ST
      00AD 2C         0229          XDC
      00AE 17         0230          ST
      00AF 03         0231          LR    A,QL
      00B0 210F       0232          NI    H'0F'
      00B2 2430       0233          AI    H'30'
      00B4 2539       0234          CI    H'39'
      00B6 8103   00BA 0235         BP    SH3
      00B8 2407       0236          AI    H'07'
      00BA 17         0237 SH3      ST
      00BB 2C         0238          XDC
      00BC 17         0239          ST
                      0240  *
      00BD 2A0169 0169 0241         DCI   MSG1
      00C0 71         0242          LIS   1
      00C1 5C         0243          LR    [illegible],A
      00C2 2A3653 3653 0244         DCI   H'3653'
```

```
MAIN CALLING PROGRAM-VERSN 4
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

     00C5 9009   00CF 0245              BF     BJA
                      0246  *
                      0247  *****
                      0248  * END AUTOMATIC THRESHOLD SETTING SEQUENCE
                      0249  *****
                      0250  *
     00C7 2A0181 0181 0251  FRZ         DCI    MSG2
     00CA 71              0252              LIS    1
     00CB 50              0253              LR     0,A
     00CC 283653 3653 0254              PI     H'3653'
                      0255  *
     00CF 2006            0256  BJA         LI     LINEU       INITIALIZE LINE CTR
     00D1 50              0257              LR     0,A         S0 IS HIGH BYTE
     00D2 20A4            0258              LI     LINEL
     00D4 51              0259              LR     1,A         S1 IS LOW BYTE
                      0260  *
     00D5 2000            0261              LI     ENCMD       OPEN UP CMD CHANNEL
     00D7 35              0262              OUTS   5
     00D8 48              0263  NEWLN       LR     A,8
     00D9 2500            0264              CI     H'00'
                      0265  *
     00DB 842E   01CA 0266              BZ     NLSOFT
                      0267  *
     00DD 2003            0268  NLHARD      LI     HARDLMJ     SEND LMJ
     00DF 59              0269              LR     9,A
     00E0 280000 0000 0270              PI     XMITS
                      0271  *
                      0272  ****DELAY******
                      0273  *
     00E3 20FE            0274              LI     254         WAIT 18 US
     00E5 1F              0275  DL1         INC
     00E6 94FE   00E5 0276              BNZ    DL1
                      0277  *
                      0278  ****END DELAY***
                      0279  *
     00E8 2020            0280              LI     ENCCD       OPEN DATA CHAN
                      0281  *------------------DATA CHANNEL OPEN
     00EA 35              0282              OUTS   5
                      0283  *
     00EB 280000 0000 0284              PI     ENDLN       WAIT FOR END OF LINE
                      0285  *
     00EE 2000            0286              LI     ENCMD       OPEN CMD CHANNEL
                      0287  *----DATA CHANNEL CLOSED -------------------
     00F0 35              0288              OUTS   5
                      0289  *
     00F1 2000            0290              LI     HARDFIL     SEND FILL CMD
     00F3 59              0291              LR     9,A
     00F4 280000 0000 0292              PI     XMITS
                      0293  *
                      0294  *****DELAY*******
                      0295  *
     00F7 20F0            0296              LI     240         WAIT 144 US
     00F9 1F              0297  DL2         INC
     00FA 94FE   00F9 0298              BNZ    DL2
                      0299  *
                      0300  *****END DELAY*****
                      0301  *
     00FC 2003            0302              LI     HARDADV     ADVANCE PAPER
     00FE 59              0303              LR     9,A
     00FF 280000 0000 0304              PI     XMITS
                      0305  *
```

```
MAIN CALLING PROGRAM-VERSN 4
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

                      0306  *****DELAY********
                      0307  *
      0102 20FE       0308          LI     254       WAIT 18 US
      0104 1F         0309  DL3     INC
      0105 94FE  0104 0310          BNZ    DL3
                      0311  *
                      0312  *****END DELAY*******
                      0313  *
      0107 290132 0132 0314         JMP    ENDCHK    CHECK FOR LAST LINE
                      0315  *
                      0316  *
                      0317  *
      010A 2006       0318  NLSOFT  LI     SOFTEN    ENABLE TEK DISPLAY
      010C 59         0319          LR     9,A
      010D 280000 0000 0320         PI     XMITS
                      0321  *
                      0322  *****DELAY********
                      0323  *
      0110 20FE       0324          LI     254       WAIT 18 US
      0112 1F         0325  DL4     INC
      0113 94FE  0112 0326          BNZ    DL4
                      0327  *
                      0328  *****END DELAY****
                      0329  *
      0115 2020       0330          LI     ENCDD     OPEN DATA CHAN
                      0331  *-------------------DATA CHANNEL OPEN
      0117 B5         0332          OUTS   5
                      0333  *
      0118 280000 0000 0334         PI     ENDLN     WAIT FOR EOL SIG
                      0335  *
      011B 2000       0336          LI     ENCMD     OPEN CMD CHANNEL
                      0337  *------------------DATA CHANNEL CLOSED
      011D B5         0338          OUTS   5
                      0339  *
      011E 2003       0340          LI     SOFTDSB   DISABLE TEK-DISPLAY
      0120 59         0341          LR     9,A
      0121 280000 0000 0342         PI     XMITS
                      0343  *
      0124 2004       0344          LI     SOFTINY   SEND INCREMENT Y CMD
      0126 59         0345          LR     9,A
      0127 280000 0000 0346         PI     XMITS
                      0347  *
                      0348  *****DELAY********
                      0349  *
      012A 20FE       0350          LI     254
      012C 1F         0351  DL5     INC              WAIT 18 US
      012D 94FE  012C 0352          BNZ    DL5
                      0353  *
                      0354  *****END DELAY***
                      0355  *
      012F 290132 0132 0356         JMP    ENDCHK
                      0357  **********************************
      0132 70         0358  ENDCHK  CLR              IF FB SENSE 5
      0133 BC         0359          OUTS   0         =1 THEN LOOP
      0134 A0         0360          INS    0         UNTIL FB SENSE
      0135 2120       0361          NI     H'20'     =0
      0137 2500       0362          CI     H'00'
      0139 8407  0141 0363          BZ     NORMCNT
      013B 2001       0364          LI     H'01'
      013D 51         0365          LR     1,A
      013E 2000       0366          LI     H'00'
```

```
MAIN CALLING PROGRAM-VERSN 4
ERRS  LOC OBJECT ADDR LINE           SOURCE STATEMENT

      0140 50          0367              LR    0,A
      0141 41          0368  NORMCNT     LR    A,1
      0142 2400        0369              AI    0           CHECK FOR LAST LINE
      0144 9407   014C 0370              BNZ   OK
      0146 40          0371              LR    A,0
      0147 2400        0372              AI    0
      0149 8406   0150 0373              BZ    DONE
      014B 30          0374              DS    0
      014C 31          0375  OK          DS    1
      014D 2900D8 00D8 0376              JMP   NEWLN
      0150 48          0377  DONE        LR    A,8
      0151 2500        0378              CI    H'00'
      0153 8412   0166 0379              BZ    SKIPSOF
                       0380  *
                       0381  *PRINTER FINAL SECTION--------------------
                       0382  *
      0155 200F        0383              LI    HARDCUT     SEND CUT CMD
      0157 59          0384              LR    9,A
      0158 280000 0000 0385              PI    XMITS
                       0386  *
                       0387  *********DELAY
                       0388  *
      015B 2076        0389              LI    246
      015D 1F          0390  CDL         INC               WAIT FOR CUT/
      015E 94FE   015D 0391              BNZ   CDL
                       0392  *
                       0393  *********END DELAY
                       0394  *
      0160 2037        0395              LI    HARDOFF     SEND PRINTER OFF CMD
      0162 59          0396              LR    9,A
      0163 280000 0000 0397              PI    XMITS
                       0398  *
                       0399  *
                       0400  *
      0166 290005 0005 0401  SKIPSOF     JMP   OVER        RUN PROGRAM AGAIN
                       0402  *
                       0403  *
      0169 0016        0404  MSG1        DC    HL2'0016'
      016B 544852      0405              DC    C'THRESHOLD RESET '
      017B 544F20      0406              DC    C'TO ***'
      0181 0017        0407  MSG2        DC    HL2'0017'
      0183 544852      0408              DC    C'THRESHOLD FROZEN '
      0194 415420      0409              DC    C'AT ***'
                       0410  *
                       0411  *
                       0412              END
00 ERRS
```

```
FSTLN
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

                 0000 0001 FSTLN    RORG  0
                      0002          TITLE 'FSTLN'
                      0003 *
                      0004 * WRITTEN BY RALPH L. VINCIGUERRA 12/80
                      0005 *
                      0006 * THIS IS A SUBR WHICH WAITS FOR THE
                      0007 * SIGNAL CALLED PRINTLINE TO MAKE A
                      0008 * RISING TRANSITION SIGNALLING THE
                      0009 * END OF A SCAN LINE, AND TIME TO
                      0010 * SEND COMMANDS.
                      0011 * DUE TO AN INVERSION IN THE
                      0012 * INTERFACE THE ACTUAL LINE IN THE
                      0013 * SCANNER MAKES A FALLING TRANSITION.
                      0014 *
                      0015 *
                 0040 0016 ENSENS   EQU   H'40'
                      0017 *
                      0018 *
      0000 2040       0019          LI    ENSENS     ENABLE SENSE INPUTS
      0002 B5         0020          OUTS  5
                      0021 *
      0003 70         0022 LP1      CLR              LOOP UNTIL FALSE
      0004 B4         0023          OUTS  4
      0005 A4         0024          INS   4
      0006 2101       0025          NI    H'01'
      0008 94FA  0003 0026          BNZ   LP1
      000A 70         0027 LP2      CLR              LOOP UNTIL TRUE
      000B B4         0028          OUTS  4
      000C A4         0029          INS   4
      000D 2101       0030          NI    H'01'
      000F 84FA  000A 0031          BZ    LP2
      0011 1C         0032          POP
                      0033          END
00 ERRS
```

```
ENDLN
ERRS  LOC OBJECT ADDR LINE           SOURCE STATEMENT

                 0000 0001  ENDLN    RORG  0
                      0002           TITLE 'ENDLN'
                      0003  *
                      0004  * WRITTEN BY RALPH L. VINCIGUERRA 12/80
                      0005  *
                      0006  * THIS IS A SUBR WHICH WAITS FOR THE
                      0007  * SIGNAL CALLED PRINTLINE TO MAKE A
                      0008  * RISING TRANSITION SIGNALLING THE
                      0009  * END OF A SCAN LINE, AND TIME TO
                      0010  * SEND COMMANDS.
                      0011  * DUE TO AN INVERSION IN THE
                      0012  * INTERFACE THE ACTUAL LINE IN THE
                      0013  * SCANNER MAKES A FALLING TRANSITION.
                      0014  *
                      0015  *
                      0016  * THIS SUBR ALSO WILL ONLY WAIT
                      0017  * ABOUT 10MS FOR THE
                      0018  * TRANSITION TO OCCUR. IF THE TRANSITION
                      0019  * TAKES MORE THE LINE COUNTER IS SET
                      0020  * THE THE END OF THE PAGE AND THE
                      0021  * MAIN PROGRAM CONCLUDES.
                 0040 0022  ENSENS   EQU   H'40'
                      0023  *
                      0024  *
      0000 2040       0025           LI    ENSENS    ENABLE SENSE INPUTS
      0002 35         0026           OUTS  5
                      0027  *
      0003 20FF       0028           LI    D'255'
      0005 59         0029           LR    9,A       INITIALIZE CNT REG
                      0030  *
      0006 70         0031  LP1      CLR             LOOP UNTIL FALSE
      0007 34         0032           OUTS  4
      0008 A4         0033           INS   4
      0009 2101       0034           NI    H'01'
      000B 8406  0012 0035           BZ    RDY
      000D 39         0036           DS    9
      000E 8410  001F 0037           BZ    DUMPOUT
      0010 90F5  0006 0038           BR    LP1
                      0039  *
      0012 20FF       0040  RDY      LI    D'255'
      0014 59         0041           LR    9,A
      0015 70         0042  LP2      CLR             LOOP UNTIL TRUE
      0016 34         0043           OUTS  4
      0017 A4         0044           INS   4
      0018 2101       0045           NI    H'01'
      001A 9408  0023 0046           BNZ   GO
      001C 39         0047           DS    9
      001D 94F7  0015 0048           BNZ   LP2
      001F 2000       0049  DUMPOUT  LI    D'00'
      0021 50         0050           LR    0,A
      0022 51         0051           LR    1,A
      0023 1C         0052  GO       POP
                      0053           END
00 ERRS
```

```
XMITS
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

                     0000 0001  XMITS    PORG  0
                          0002  *
                          0003           TITLE 'XMITS'
                          0004  *
                          0005  * WRITTEN BY RALPH L. VINCIGUERRA 12/80
                          0006  *
                          0007  *
                          0008  * THIS SUBR IS USED TO SEND THE COMMANDS
                          0009  * TO THE PRINTER OR THE TEK DISPLAY.
                          0010  * IT EXPECTS THAT THE COMMAND CHANNEL
                          0011  * HAS ALREADY BEEN OPENED THRU PORT 5,
                          0012  * AND THAT THE COMMAND TO BE SENT IS
                          0013  * WAITING IN REGISTER 9 TO BE SENT TO
                          0014  * PORT 9.
                          0015  *
      0000 49             0016           LR    A,9       PUT CMD ON PORT 9
      0001 39             0017           OUTS  9
      0002 2010           0018           LI    H'10'     LOAD CMD INTO LOGIC
      0004 39             0019           OUTS  9
      0005 70             0020           CLR
      0006 39             0021           OUTS  9
      0007 2002           0022           LI    H'02'     SEND SYNC PULSE
      0009 39             0023           OUTS  9
      000A 70             0024           CLR
      000B 39             0025           OUTS  9
                          0026  *
      000C 1C             0027           POP             POP RET ADDR
                          0028           END
00 ERRS
```

```
QUICK THRESHOLD SAMPLER,V6
ERRS  LOC OBJECT ADDR LINE           SOURCE STATEMENT

                 0000      QSET      RORG  0
                                     TITLE 'QUICK THRESHOLD SAMPLER,V6'
                           *
                           *  THIS IS THE NEXT GENERATION OF QSET
                           *  MODIFIED TO BE A RELOCATABLE MODULE.
                           *
                           *  INTENDED TO BE LINKED WITH THE MAIN
                           *  CALLING PROGRAM OF THE ELECTRO-OPTICAL
                           *  PAGE SCANNER.
                           *
                           *  INITIALIZING IS ACCOMPLISHED IN THE
                           *  MAIN CALLING PROGRAM.  STARTING VALUE
                           *  OF N AND STEP SIZE (SI) ARE DETERMINED
                           *  AT THAT TIME.
                           *
                           *
                           *  WRITTEN BY CAPT B.J. STANTON, 9 JUN 82
                           *  DEBUGGED FROM QSET3, 21 JUN 82
                           *  EDITED FROM QSET5, 21 JULY 82
                           *
                           *
                 0080      VCRSET    EQU   H'80'      DIG VIDEO CNT RESET
                 0002      CNT       EQU   2          SAMPLE PGM COUNTER
                 0003      STEP      EQU   3          THRESHOLD STEP SIZE
                 0004      NU        EQU   4          THRESHOLD HIGH BYTE
                 0005      NL        EQU   5          THRESHOLD LOW  BYTE
                 0006      MTCU      EQU   6          MAX DIG VIDEO HI BYT
                 0007      MTCL      EQU   7          MAX DIG VIDEO LO BYT
                 000A      MINU      EQU   10         MINUEND HIGH BYTE
                 000B      MINL      EQU   11         MINUEND LOW  BYTE
                 0040      ENSENS    EQU   H'40'
                           *
                           *
                           * -----------SUBROUTINE SAMPLE--------------
                           *
                           * THIS SUBROUTINE HAS PROVISIONS FOR A VAR-
                           * IABLE THRESHOLD STEP SIZE LOADED IN R3
                           * (STEP).  IT EXPECTS THE STARTING THRESHOLD
                           * VALUE TO BE LOADED IN R4,R5 (NU, NL)
                           *
      0000 77                        LIS   7          INITIALIZE
      0001 52                        LR    CNT,A      COUNTER
                           *
      0002 2080            RVC       LI    VCRSET     RESET
      0004 2713                      OUT   H'13'      VIDEO
      0006 70                        CLR              COUNTERS
      0007 2713                      OUT   H'13'
                           *
      0009 45                        LR    A,NL       INCREMENT
      000A C3                        AS    STEP       THRESHOLD N
      000B 55                        LR    NL,A       VALUE ONE
      000C 2712                      OUT   H'12'
      000E 44                        LR    A,NU       STEP
      000F 19                        LNK
      0010 54                        LR    NU,A
      0011 2713                      OUT   H'13'
                           *
                           * TEST FOR END OF PRINTLINE-----------------
                           *
      0013 2040                      LI    ENSENS
      0015 B5                        OUTS  5
```

QUICK THRESHOLD SAMPLER/76

```
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

     0016 70                  PL1     CLR             LOOP UNTIL FALSE
     0017 B4                          OUTS   4
     0018 A4                          INS    4
     0019 2101                        NI     H'01'
     001B 94FA     0016               BNZ    PL1
     001D 70                  PL2     CLR             LOOP UNTIL TRUE
     001E B4                          OUTS   4
     001F A4                          INS    4
     0020 2101                        NI     H'01'
     0022 84FA     001D               BZ     PL2
                              *
                              * STORE NEW VTC IN SUBTRAHEND (K)------------
                              *
     0024 70                          CLR
     0025 2711                        OUT    H'11'
     0027 2611                        IN     H'11'
     0029 18                          COM
     002A 04                          LR     KU,A
     002B 70                          CLR
     002C 2710                        OUT    H'10'
     002E 2610                        IN     H'10'
     0030 18                          COM
     0031 05                          LR     KL,A
                              *
                              * LOAD MINUEND WITH MAX VTC (MTC)------------
                              *
     0032 46                          LR     A,MTCU
     0033 5A                          LR     MINU,A
     0034 47                          LR     A,MTCL
     0035 5B                          LR     MINL,A
                              *
                              * SUBTRACT FOR SIGN OF RESULT----------------
                              *
     0036 01                          LR     A,KL     LOAD SUBLOW AND
     0037 18                          COM             COMPLEMENT
     0038 CB                          AS     MINL     SUBLOW + MINLOW
     0039 5B                          LR     MINL,A   STORE IN MINLOW
     003A 4A                          LR     A,MINU   CARRY TO
     003B 19                          LNK             MINHI
     003C 5A                          LR     MINU,A
     003D 4B                          LR     A,MINL   ADD 1 TO MAKE
     003E 1F                          INC             2'S COMPLEMENT
     003F 4A                          LR     A,MINU   CARRY TO
     0040 19                          LNK             MINHI
     0041 5A                          LR     MINU,A
     0042 00                          LR     A,KU     LOAD SUBHI AND
     0043 18                          COM             COMPLEMENT
     0044 CA                          AS     MINU     SUBHI + MINHI
                              *
                              * END OF SUBTRACT FOR SIGN------------------
                              *
     0045 8209     004F               BC     SKIP
     0047 00                          LR     A,KU     REPLACE MTC
     0048 56                          LR     MTCU,A   WITH NEW MAXIMUM
     0049 01                          LR     A,KL     VTC
     004A 57                          LR     MTCL,A
                              *
     004B 44                          LR     A,NU     STORE NEW
     004C 06                          LR     QU,A     THRESHOLD VALUE
     004D 45                          LR     A,NL     N GIVING MTC
     004E C7                          LR     QL,A
```

```
QUICK THRESHOLD SAMPLER,V6
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

                      0123  *
      004F 32         0124  SKIP      DS    CNT
      0050 94B1  0002 0125            BNZ   RVC
                      0126  *
                      0127  * END OF SUBROUTINE SAMPLE------------------
                      0128  *
                      0129  * DETERMINE STARTING VALUE OF NEW RANGE OF
                      0130  * N TO BE SAMPLED
                      0131  *
                      0132  * SUBROUTINE SUBTRACT-----------------
                      0133  * LOADS:
                      0134  * MINUEND     IN R10, R11 (M)
                      0135  * SUBTRAHEND  IN R12, R13 (K)
                      0136  * RESULT      IN R10, R11 (M)
                      0137  *
                      0138  * FIRST LOAD VALUES-------------------
                      0139  *
      0052 02         0140            LR    A,QU       LOAD
      0053 5A         0141            LR    MINU,A     UP
      0054 03         0142            LR    A,QL       IN
      0055 5B         0143            LR    MINL,A     MINUEND
                      0144  *
      0056 43         0145            LR    A,STEP     LOAD STEP
      0057 05         0146            LR    KL,A       IN
      0058 70         0147            CLR              SUBTRAHEND
      0059 04         0148            LR    KU,A
                      0149  *
                      0150  * THEN SUBTRACT-----------------------
                      0151  *
      005A 01         0152            LR    A,KL       LOAD SUBLOW AND
      005B 18         0153            COM              COMPLEMENT
      005C CB         0154            AS    11         SUBLOW + MINLOW
      005D 5B         0155            LR    11,A       STORE IN MINLOW
      005E 9204  0063 0156            BNC   SB1        IF CARRY THEN
      0060 4A         0157            LR    A,10       INCREMENT
      0061 1F         0158            INC              MINHI
      0062 5A         0159            LR    10,A
                      0160  *
      0063 4B         0161  SB1       LR    A,11       ADD 1 TO MAKE
      0064 1F         0162            INC              2'S COMPLEMENT
      0065 5B         0163            LR    11,A
      0066 9204  006B 0164            BNC   SB2        IF CARRY THEN
      0068 4A         0165            LR    A,10       INCREMENT
      0069 1F         0166            INC              MINHI
      006A 5A         0167            LR    10,A
                      0168  *
      006B 00         0169  SB2       LR    A,KU       LOAD SUBHI AND
      006C 18         0170            COM              COMPLEMENT
      006D CA         0171            AS    10         SUBHI + MINHI
      006E 5A         0172            LR    10,A       STORE IN MINHI
                      0173  *
                      0174  * FINALLY STORE NEW STARTING THRESHOLD-------
                      0175  *
                      0176  *
      006F 4A         0177            LR    A,MINU
      0070 54         0178            LR    NU,A
      0071 4B         0179            LR    A,MINL
      0072 55         0180            LR    NL,A
                      0181  *
                      0182  * ALTER STEP SIZE--------------------------
                      0183  *
```

```
QUICK THRESHOLD SAMPLER,V6
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

      0073 43           0184          LR     A,STEP      DIVIDE STEP
      0074 12           0185          SR     1           SIZE BY 4
      0075 12           0186          SR     1
      0076 53           0187          LR     STEP,A
      0077 1C           0188          POP
                        0189   *
                        0190   * END OF SUBROUTINE SAMPLE----------------
                        0191   *
                        0192          END
00 ERRS
```

LISTING OF EXEC FILE 'LNKEO' WHICH LINKS TOGETHER
THE INDIVIDUAL SOFTWARE MODULES THAT FORM 'EOPS-'

```
LINK 1 CLEAR ORG 0 MAIN4,10:1
LINK 1 FSTLN,10:1
LINK 1 ENDLN,10:1
LINK 1 XMITS,10:1
LINK 1 QSET ,10:1
ASS CI TTI
```

LINKING INFORMATION FOR 'EOPS-'

FORMULATOR LOADER

SYMBOL ADDR

MAIN4 0000

NEXT ADDR: 019A 0000

UNDEF SYM:
ENDLN FSTLN XMITS QSET

FORMULATOR LOADER

SYMBOL ADDR

FSTLN 019A

NEXT ADDR: 01AC 0000

UNDEF SYM:
ENDLN XMITS QSET

FORMULATOR LOADER

SYMBOL ADDR

ENDLN 01AC

NEXT ADDR: 01D0 0000

UNDEF SYM:
XMITS QSET

FORMULATOR LOADER

SYMBOL ADDR

XMITS 01D0

NEXT ADDR: 01DD 0000

UNDEF SYM:
QSET

FORMULATOR LOADER

SYMBOL ADDR

QSET 01DD

NEXT ADDR: 0255 0000

UNDEF SYM:

APPENDIX C

COMPUTER SIMULATIONS

These simulations use the APL programs QSET1 and QSET2 on the following page to emulate the flowchart of Figure 5.5. The VTC data used in the simulations were taken with the scanner and F8 under operational conditions as noted in Table C.1. Therefore the simulated performance accurately represents the actual behavior of QSET when implemented with the F8 and incorporated with the normal page-scanning sequence.

A few details deserve special attention as one examines these simulations. First, the smallest step size of QSET1 is S4 = 2 whereas the smallest step size of QSET2 is S4 = 1. In other words, QSET1 is fundamentally limited to only being able to pinpoint Np (the value of N producing the peak of the VTC curve, MTC) within an error of one millivolt. For this reason, errors of one millivolt with QSET1 are ignored when comparing QSET1 to QSET2 in Table C.3. Next, errors in the value of N are signed. If QSET produced an N-value less than the actual value of Np, then the error is negative (^), and if the QSET result is greater than the actual value of Np, then the error is positive. However, it is more significant to ignore the sign and evaluate the MAGNITUDE of the QSET error since this will reveal information on how far QSET "misses" the actual VTC peak, or equivalently, how far from optimum the threshold will be set due to sampling error. Finally it is important to understand that the QSET algorithm was designed to find the peak of a relatively

smooth discrete curve with only one obvious maximum. But some of the data sets used in the simulations have much different characteristics, and it is instructive to note the behavior of the QSET algorithm in these situations.

The VTC data sets can be grouped into three general categories: (I) data sets using ECP A under normal conditions; (II) data sets using ECP A under abnormal conditions; and (III) data sets using other ECPs under normal conditions. Table C.2 lists the data sets belonging to each group, and Table C.3 summarizes the results of the simulation data. Although the data base is relatively small due to time constraints in this research, a few significant trends can still be identified. Notice first that the performance of both QSET1 and QSET2 are identical for Category I data sets. Looking at the individual simulations reveals that the same errors occurred mainly due to similar multiples in the samples taken. Also, the largest error occurred with data set A6232 which had an abnormal shape. And in general, it is important to realize that sampling errors are a product of the uncertainty in the VTC curve itself.

The performance with Category II data is a perfect example of the problem discussed in Chapter 5 concerning the occasion when the range of significant VTC information (RV) is smaller than the initial step size (S1). By examining the QSET1 simulations with data sets A606A and A606D, it can be seen that the algorithm will "freeze" on the initial sample because no significant VTC data is ever encountered. Recall however that

QSET2 was designed to overcome this specific problem, and as noted in the simulation results, its performance is excellent.

QSET evaluations with Category III data sets are more for example of the dependence of the algorithm on a properly shaped VTC curve. As discussed in Chapter 3, the CALIBRATION PATTERN must produce a VTC curve whose peak is at the value of N giving the optimum resolution in the scanner's output. While both algorithms faithfully locate the peaks in data sets B6062, C6062, and D6062, remember that these data sets are generated from constant-frequency ECPs that give erroneous VTC maximums. The large sampling errors occurring with data sets E6062 and F6062 are due to the significant ambiguities present in these VTC curves. Therefore it can be seen that ATC performance in general will be extremely unpredictable when scanning anything other than the proper CALIBRATION PATTERN.

TABLE C.1

VIDEO TRANSITION COUNT

DATA SETS

DATA CODE KEY:

First character:	Indicates ECP used
Second character:	Indicates month data taken
Third and fourth character:	Indicates day data taken
Fifth character:	Indicates run on given day

DATA CODE	REMARKS
A5261	Old green fluorescents used
A6061	Old soft white fluorescents used
A6062	Old cool white fluorescents used
B6062	Old cool white fluorescents used
C6062	Old cool white fluorescents used
D6062	Old cool white fluorescents used
E6062	Old cool white fluorescents used
F6062	Old cool white fluorescents used
A6063	Old warm white fluorescents used
A6064	Only one warm white fluorescent used
A6066	Old cool white fluorescents used; Yellow paper used as background
A606A	Old cool white fluorescents used; Red paper used as background
A606D	Old cool white fluorescents used; Navy blue paper used as background
A6071	Old cool white fluorescents used
A6072	Same conditions as A6071; 5 minutes later
A6073	Same conditions as A6072; 5 minutes later
A6074	Same conditions as A6073; 5 minutes later
A6075	Same conditions as A6074; 5 minutes later
A6231	New green fluorescents used
A6232	New cool white fluorescents used
A6233	New warm white fluorescents used

TABLE C.2

DATA SET GROUPINGS

Category I	Category II	Category III
A5261	A6064	B6062
A6061	A6066	C6062
A6062	A606A	D6062
A6063	A606D	E6062
A6071		F6062
A6072		
A6073		
A6074		
A6075		
A6231		
A6232		
A6233		

TABLE C.3

STATISTICAL SUMMARY OF QSET PERFORMANCE

	CAT I	CAT II	CAT III
Occurrences of Errors with QSET1 (> 1 millivolt)	25%	50%	40%
Occurrences of Errors with QSET2 (> 0 millivolt)	25%	0%	40%
Expected Value of Error with QSET1 (mV)	3.25	92.0	24.4
Standard Deviation of Error with QSET1 (mV)	7.62	106.3	35.3
Expected Value of Error with QSET2 (mV)	3.25	0.0	22.2
Standard Deviation of Error with QSET2 (mV)	7.62	0.0	35.7

```
∇QSET1[□]∇

    ∇ QSET1 A;F;F1;F2;X1;P;L;E;E  E2;MAINCOUNT;N;MTC;STEP;LINECOUNT
[1]    ⍝ THIS PROGRAM SIMULATES THE QSAT ALGORITHM WITH THE
[2]    ⍝ ENTIRE RANGE OF N: 0 TO 1024.
[3]    ⍝
[4]    ⍝ THE FIRST PART TAKES THE TRUNCATED DATA SET AND STRETCHES
[5]    ⍝ IT TO COVER THE ENTIRE RANGE OF N.
[6]    ⍝
[7]    X1← A[1;1] - 1
[8]    F1 ← ⍳X1
[9]    F1 ← (X1,1)⍴F1
[10]   F2 ← (X1,1)⍴1
[11]   F ← F1,F2
[12]   A ← F,[1]A
[13]   P ← ⍴A
[14]   P ← P[1]
[15]   L ← (1024 -A[P;1]+1)
[16]   E1 ← A[P;1] + ⍳L
[17]   E1 ← (L,1)⍴E1
[18]   E2 ← (L,1)⍴0
[19]   E ← E1,E2
[20]   A ← A,[1]E
[21]   ⍝
[22]   ⍝ MAIN SAMPLING PORTION OF THE PROGRAM FOLLOWS.
[23]   ⍝
[24]   MAINCOUNT ← N ← MTC ← 0
[25]   STEP ← 128
[26]  MAINLOOP:  LINECOUNT ← 7
[27]   ' '
[28]   '----------PASS ',⍕(MAINCOUNT+1)
[29]   ' '
[30]   '    N    VTC'
[31]   ' '
[32]  LINELOOP:  N ← N + STEP
[33]   → ((MTC - A[N;2]) ≥ 0)/NEXT
[34]   MTC ← A[N;2]
[35]   Q ← A[Q;1]
[36]  NEXT: (5 0)⍕A[N;]
[37]   LINECOUNT ← LINECOUNT -1
[38]   → (LINECOUNT ≠ 0)/LINELOOP
[39]   N ← Q - STEP
[40]   STEP ← STEP ÷ 4
[41]   MAINCOUNT ← MAINCOUNT + 1
[42]   → (MAINCOUNT ≠ 4)/MAINLOOP
[43]   N ← Q
[44]   ' '
[45]   ' '
[46]   'ACCORDING TO QSET1, THE'
[47]   'THRESHOLD VALUE PRODUCING'
[48]   'THE PEAK OF THE VTC CURVE IS N = ',⍕N
[49]   '
[50]   MTC ← (⌈/A[;2])
[51]   C ← 1
[52]  AGAIN: → (MTC = A[C;2])/ELSE
[53]   C ← C+1
[54]   → AGAIN
[55]  ELSE: ' '
[56]   'ACTUAL VTC PEAK ... ',⍕A[C;1]
[57]   ' '
[58]   'ERROR ... '
```

```
[illegible]
⍝ [illegible]
⍝ [illegible]
⍝
⍝ [illegible]
⍝ [illegible]
⍝
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 1024 [illegible]A[P;1]+1)
R1 ← A[P;1] − [illegible]
R1 ← ([illegible];1)⍴R1
R2 ← ([illegible];1)⍴0
R ← R1,R2
[illegible]
⍝
⍝ [illegible] SAMPLING PORTION OF THE [illegible]RAM FOLLOWS.
⍝
MAINCOUNT ← MTC ← 0
N ← 128
STEP ← 64
MAINLOOP: LINECOUNT ← 7
[illegible]
'————————————PASS ',⍕(MAINCOUNT+1)
[illegible]
[illegible]
[illegible]
LINELOOP: N ← N + STEP
→ ((MTC − A[N;2]) ≥ 0)/NEXT
MTC ← A[N;2]
[illegible] ← A[N;1]
NEXT: (5 0)⍕A[N;]
LINECOUNT ← LINECOUNT −1
→ (LINECOUNT ≠ 0)/LINELOOP
N ← N − STEP
STEP ← STEP ÷ 4
MAINCOUNT ← MAINCOUNT + 1
→ (MAINCOUNT ≠ 4)/MAINLOOP
[illegible]
[illegible]
[illegible]
'[illegible]ORDING TO USE[illegible]2, THE'
'[illegible]HOLD VALUE PRODUCING'
'THE PEAK OF THE VTC CURVE IS N = ',⍕[illegible]
[illegible]
[illegible]
[illegible] ← 1
[illegible] ← A[[illegible];2])/OIRF
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
```

QSET1 A5261

----------PASS 1

N	VTC
128	1
256	1
384	190
512	0
640	0
768	0
896	0

----------PASS 2

N	VTC
288	4
320	126
352	253
384	190
416	71
448	3
480	0

----------PASS 3

N	VTC
328	169
336	210
344	222
352	253
360	244
368	226
376	215

----------PASS 4

N	VTC
346	226
348	241
350	254
352	253
354	255
356	246
358	244

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 354

ACTUAL VTC PEAK OCCURRED AT N = 354

ERROR FROM CORRECT N IS: 0

QSET2 A5261

----------PASS 1

N	VTC
192	1
256	1
320	126
384	190
448	3
512	0
576	0

----------PASS 2

N	VTC
336	210
352	253
368	226
384	190
400	121
416	71
432	20

----------PASS 3

N	VTC
340	216
344	222
348	241
352	253
356	246
360	244
364	228

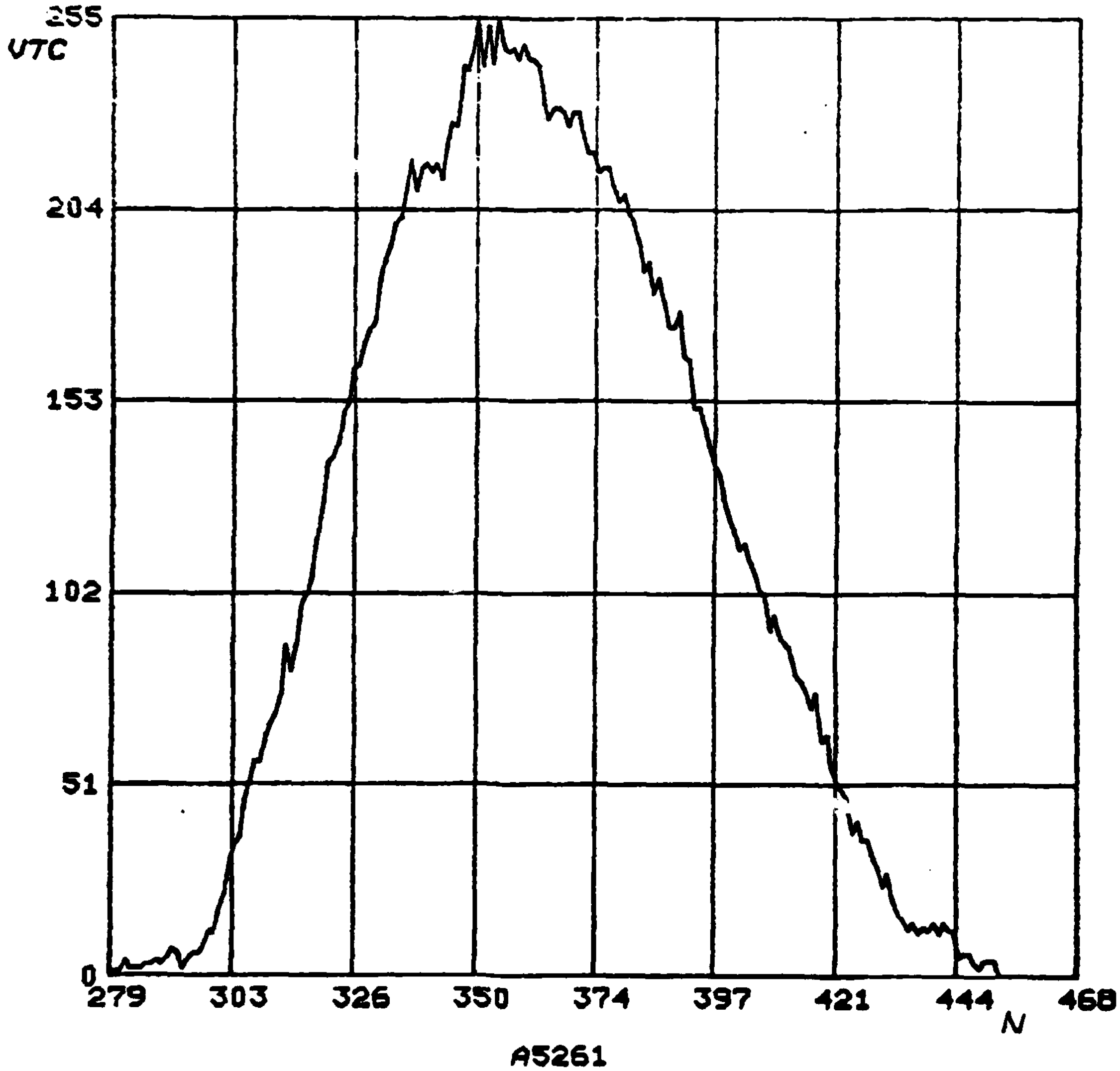
----------PASS 4

N	VTC
349	247
350	254
351	242
352	253
353	243
354	255
355	247

ACCORDING TO QSET2. THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 354

ACTUAL VTC PEAK OCCURRED AT N = 354

ERROR FROM CORRECT N IS: 0


255
VTC
204
153
102
51
0
279
303
326
350
374
397
421
444
468
N
A5261

QSET1 A6061

----------PASS 1

N	VTC
128	1
256	1
384	113
512	121
640	0
768	0
896	0

----------PASS 2

N	VTC
416	157
448	176
480	149
512	121
544	67
576	39
608	0

----------PASS 3

N	VTC
424	180
432	187
440	183
448	176
456	172
464	161
472	154

----------PASS 4

N	VTC
426	178
428	179
430	200
432	187
434	180
436	177
438	181

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 430

ACTUAL VTC PEAK OCCURRED AT N = 430

ERROR FROM CORRECT N IS: 0

QSET2 A6061

----------PASS 1

N	VTC
192	1
256	1
320	6
384	113
448	176
512	121
576	39

----------PASS 2

N	VTC
400	140
416	157
432	187
448	176
464	161
480	149
496	144

----------PASS 3

N	VTC
420	168
424	180
428	179
432	187
436	177
440	183
444	185

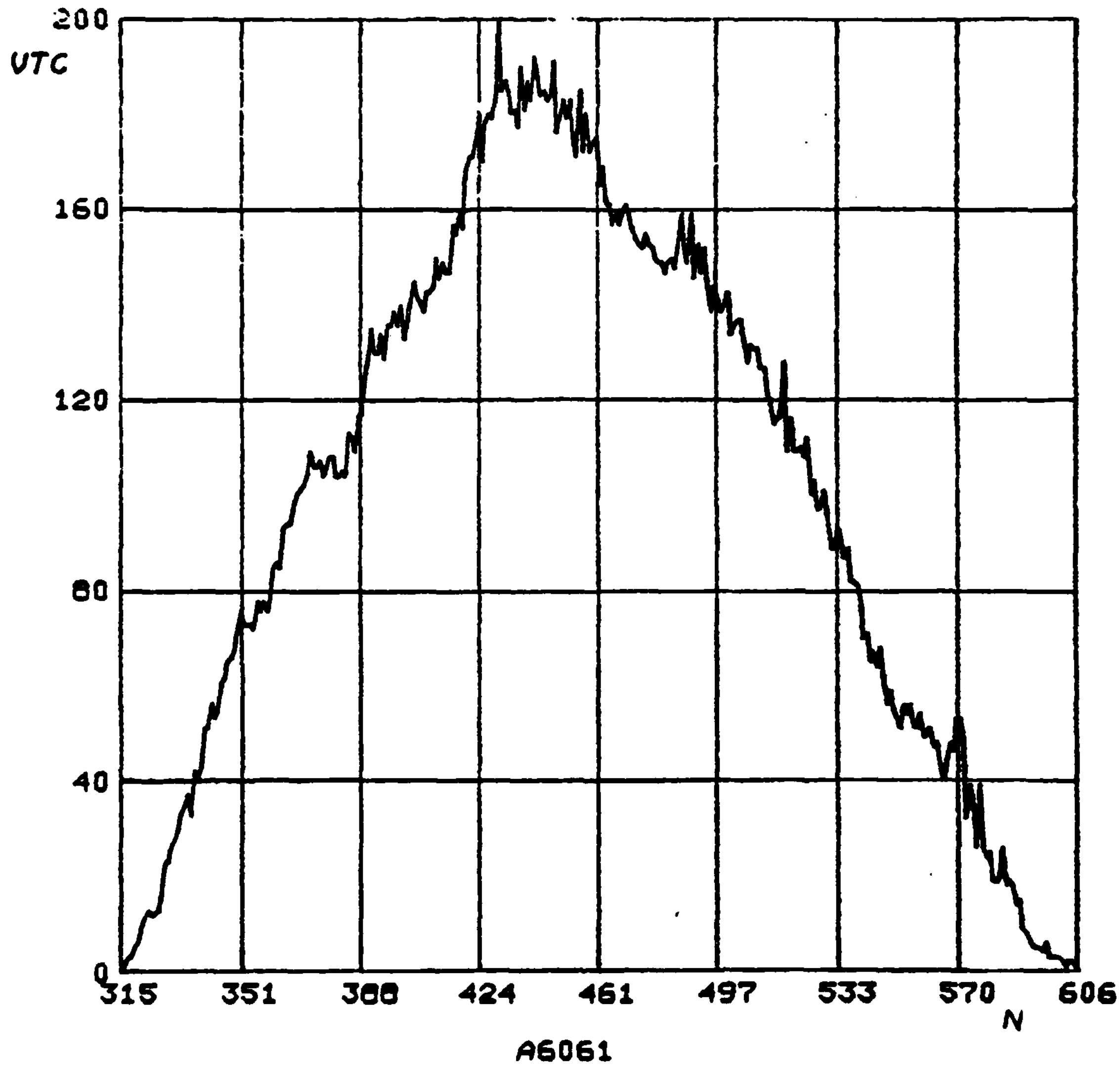
----------PASS 4

N	VTC
429	184
430	200
431	185
432	187
433	185
434	180
435	181

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 430

ACTUAL VTC PEAK OCCURRED AT N = 430

ERROR FROM CORRECT N IS: 0


200
VTC
160
120
80
40
0
315
351
388
424
461
497
533
570
606
N
A6061

QSET1 A6062

----------PASS 1

N	VTC
128	1
256	1
384	130
512	117
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	24
352	82
384	130
416	197
448	182
480	150

----------PASS 3

N	VTC
392	139
400	152
408	184
416	197
424	197
432	185
440	181

----------PASS 4

N	VTC
410	189
412	198
414	194
416	197
418	206
420	207
422	204

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 420

ACTUAL VTC PEAK OCCURRED AT N = 419

ERROR FROM CORRECT N IS: 1

QSET2 A6062

----------PASS 1

N	VTC
192	1
256	1
320	24
384	130
448	182
512	117
576	2

----------PASS 2

N	VTC
400	152
416	197
432	185
448	182
464	162
480	150
496	138

----------PASS 3

N	VTC
404	162
408	184
412	198
416	197
420	207
424	197
428	192

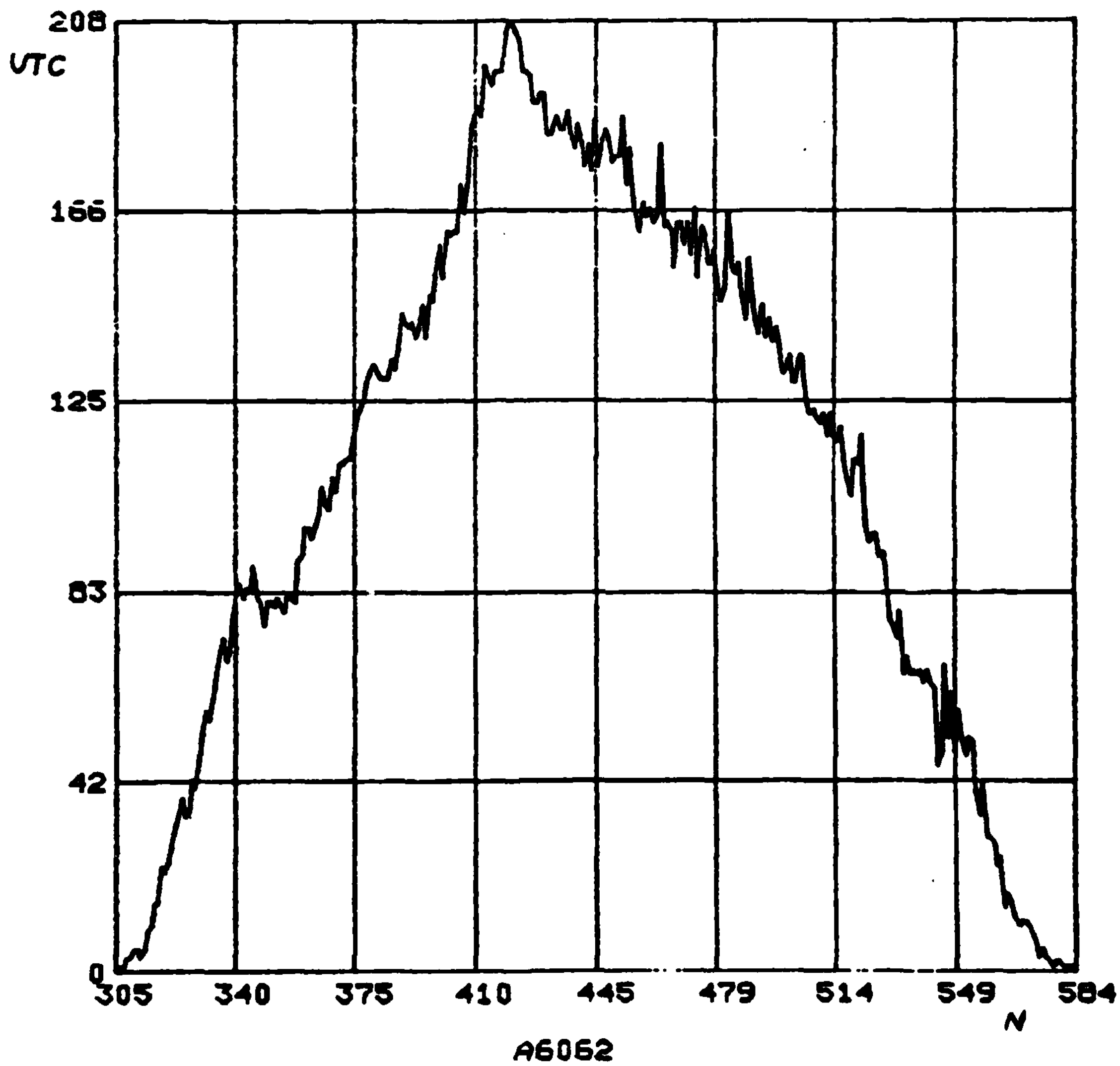
----------PASS 4

N	VTC
417	197
418	206
419	208
420	207
421	205
422	204
423	197

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 419

ACTUAL VTC PEAK OCCURRED AT N = 419

ERROR FROM CORRECT N IS: 0



208
VTC
166
125
83
42
0
305
340
375
410
445
479
514
549
584
N
A6062

QSET1 A6063

----------PASS 1

N	VTC
128	1
256	1
384	168
512	53
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	45
352	109
384	168
416	184
448	153
480	117

----------PASS 3

N	VTC
392	193
400	192
408	205
416	184
424	168
432	166
440	161

----------PASS 4

N	VTC
402	204
404	202
406	197
408	205
410	200
412	207
414	188

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 412

ACTUAL VTC PEAK OCCURRED AT N = 407

ERROR FROM CORRECT N IS: 5

QSET2 A6063

----------PASS 1

N	VTC
192	1
256	1
320	45
384	168
448	153
512	53
576	0

----------PASS 2

N	VTC
336	85
352	109
368	131
384	168
400	192
416	184
432	166

----------PASS 3

N	VTC
388	178
392	193
396	202
400	192
404	202
408	205
412	207

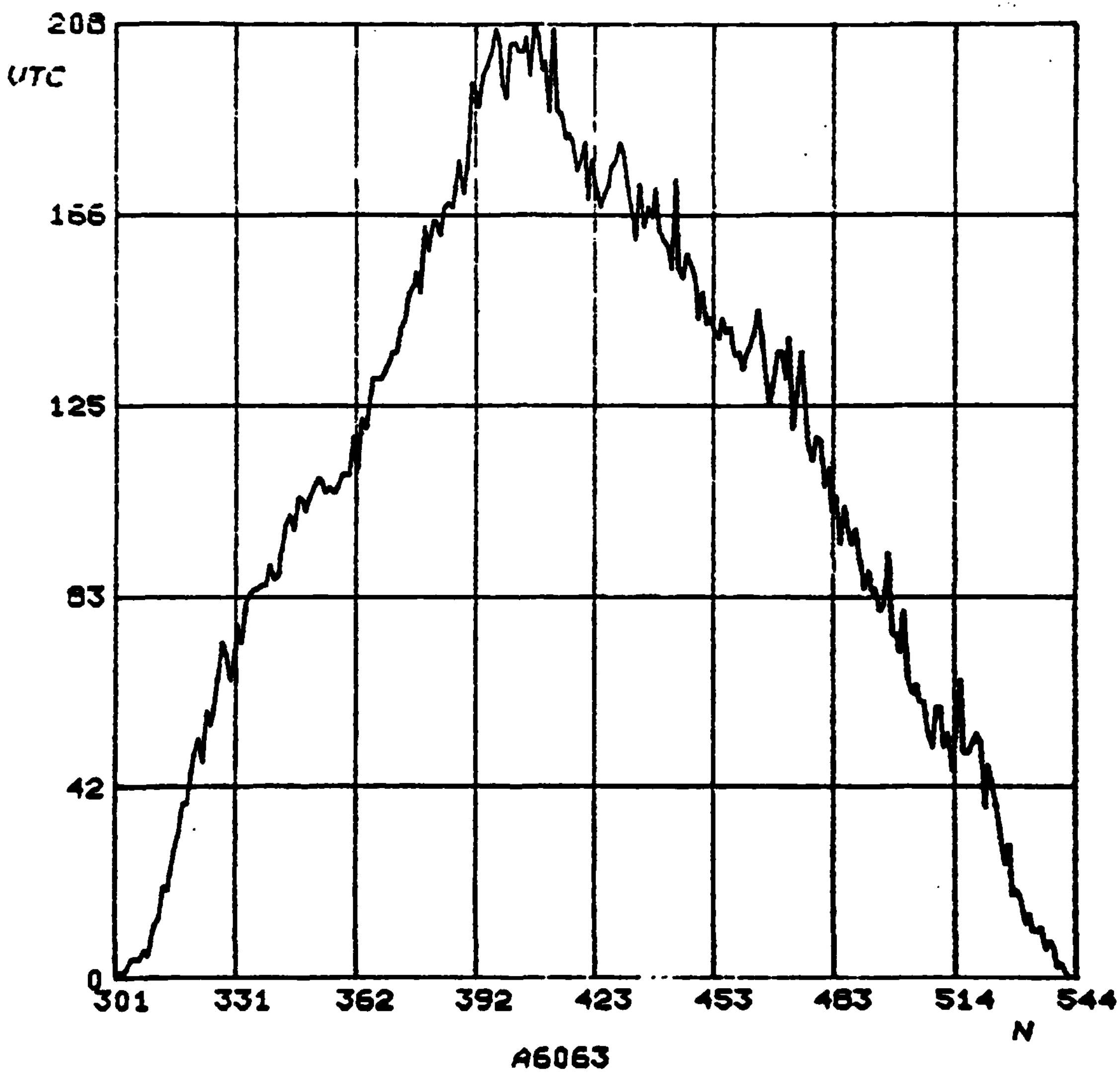
----------PASS 4

N	VTC
409	198
410	200
411	189
412	207
413	189
414	188
415	183

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 412

ACTUAL VTC PEAK OCCURRED AT N = 407

ERROR FROM CORRECT N IS: 5


208
UTC
166
125
83
42
0
301
331
362
392
423
453
483
514
544
N
A6063

QSET1 A6064

----------PASS 1

N	VTC
128	1
256	1
384	35
512	0
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	157
352	164
384	35
416	0
448	0
480	0

----------PASS 3

N	VTC
328	174
336	206
344	189
352	164
360	137
368	110
376	88

----------PASS 4

N	VTC
330	186
332	179
334	198
336	206
338	211
340	202
342	193

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 338

ACTUAL VTC PEAK OCCURRED AT N = 338

ERROR FROM CORRECT N IS: 0

QSET2 A6064

----------PASS 1

N	VTC
192	1
256	1
320	157
384	35
448	0
512	0
576	0

----------PASS 2

N	VTC
272	1
288	1
304	74
320	157
336	206
352	164
368	110

----------PASS 3

N	VTC
324	149
328	174
332	179
336	206
340	202
344	189
348	175

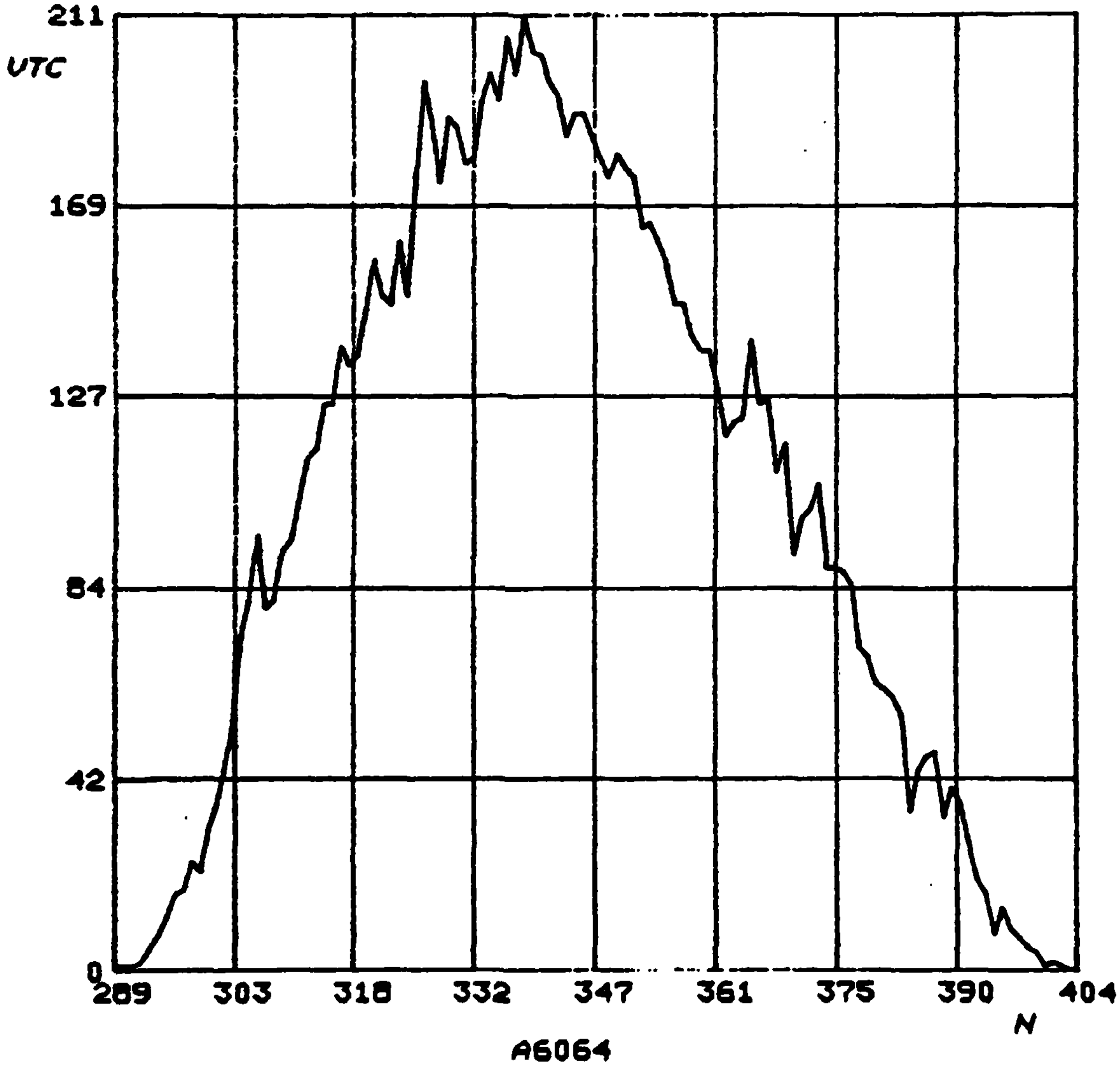
----------PASS 4

N	VTC
333	192
334	198
335	192
336	206
337	198
338	211
339	203

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 338

ACTUAL VTC PEAK OCCURRED AT N = 338

ERROR FROM CORRECT N IS: 0


211
UTC
169
127
84
42
0
289
303
318
332
347
361
375
390
404
N
A6064

QSET1 A6066

----------PASS 1

N	VTC
128	1
256	1
384	154
512	1
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	63
352	179
384	154
416	119
448	87
480	16

----------PASS 3

N	VTC
328	103
336	135
344	175
352	179
360	177
368	164
376	162

----------PASS 4

N	VTC
346	167
348	174
350	177
352	179
354	180
356	173
358	172

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 354

ACTUAL VTC PEAK OCCURRED AT N = 353

ERROR FROM CORRECT N IS: 1

QSET2 A6066

----------PASS 1

N	VTC
192	1
256	1
320	63
384	154
448	87
512	1
576	0

----------PASS 2

N	VTC
336	135
352	179
368	164
384	154
400	147
416	119
432	105

----------PASS 3

N	VTC
340	159
344	175
348	174
352	179
356	173
360	177
364	169

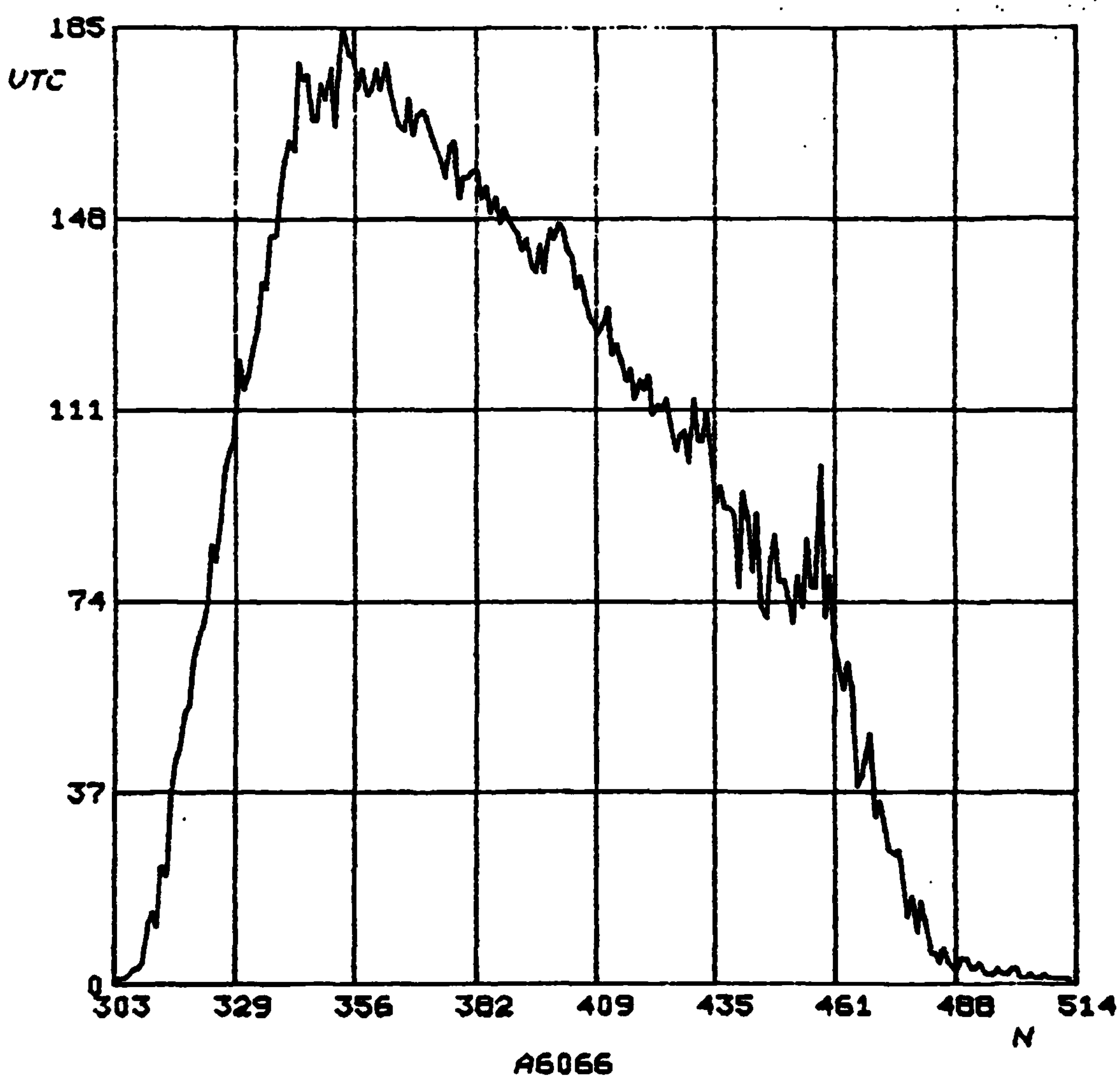
----------PASS 4

N	VTC
349	171
350	177
351	166
352	179
353	185
354	180
355	179

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 353

ACTUAL VTC PEAK OCCURRED AT N = 353

ERROR FROM CORRECT N IS: 0


185
UTC
148
111
74
37
0
303
329
356
382
409
435
461
488
514
N
A6066

QSET1 A606A

----------PASS 1

N	VTC
128	1
256	1
384	0
512	0
640	0
768	0
896	0

----------PASS 2

N	VTC
32	1
64	1
96	1
128	1
160	1
192	1
224	1

----------PASS 3

N	VTC
104	1
112	1
120	1
128	1
136	1
144	1
152	1

----------PASS 4

N	VTC
122	1
124	1
126	1
128	1
130	1
132	1
134	1

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 128

ACTUAL VTC PEAK OCCURRED AT N = 318

ERROR FROM CORRECT N IS: ^190

QSET2 A606A

----------PASS 1

N	VTC
192	1
256	1
320	188
384	0
448	0
512	0
576	0

----------PASS 2

N	VTC
272	1
288	1
304	54
320	188
336	131
352	58
368	1

----------PASS 3

N	VTC
308	109
312	171
316	194
320	188
324	183
328	147
332	152

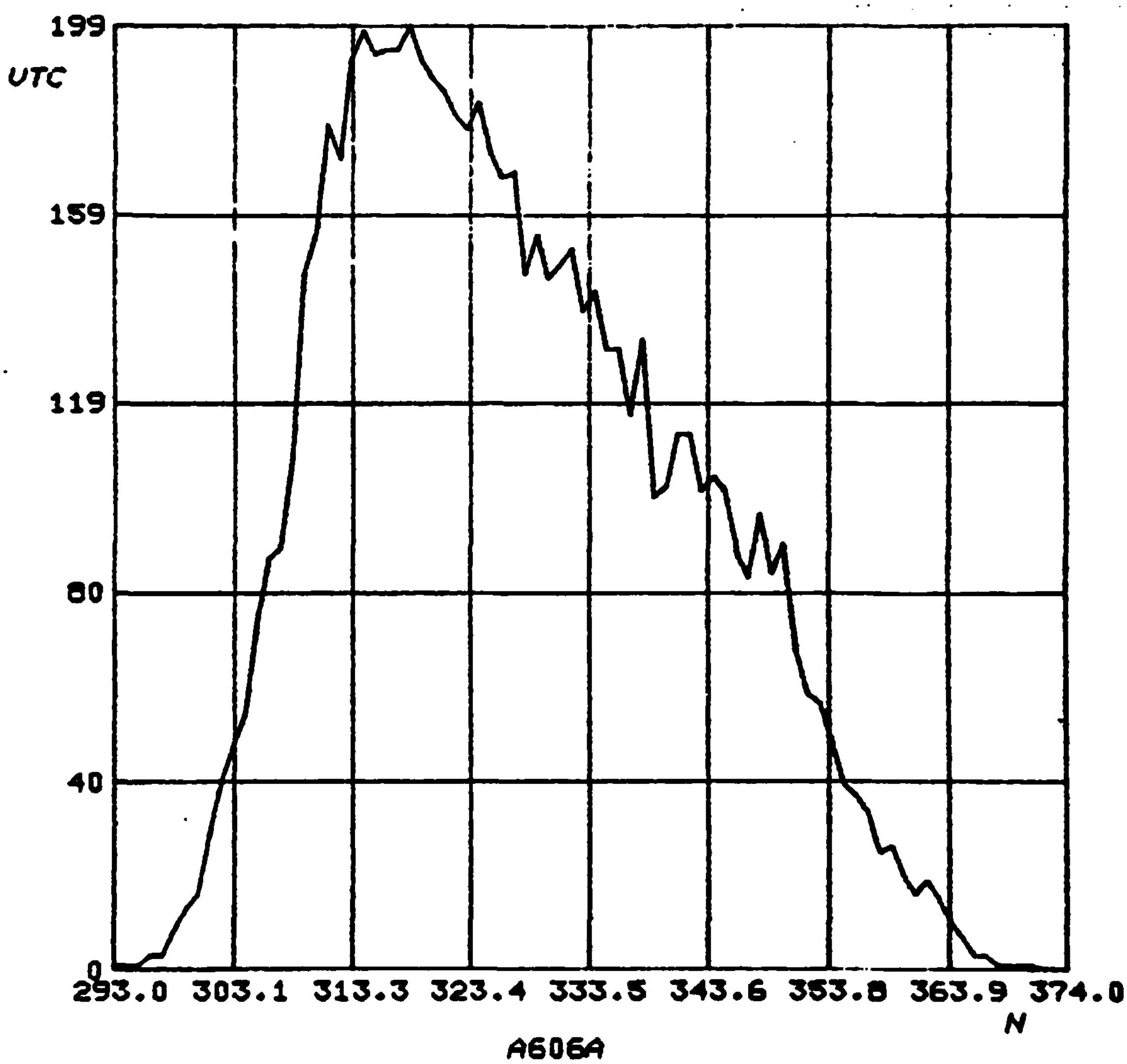
----------PASS 4

N	VTC
313	192
314	198
315	193
316	194
317	194
318	199
319	192

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 318

ACTUAL VTC PEAK OCCURRED AT N = 318

ERROR FROM CORRECT N IS: 0


199
UTC
159
119
80
40
0
293.0
303.1
313.3
323.4
333.5
343.6
353.8
363.9
374.0
N
A606A

QSET1 A606D

----------PASS 1

N	VTC
128	1
256	1
384	0
512	0
640	0
768	0
896	0

----------PASS 2

N	VTC
32	1
64	1
96	1
128	1
160	1
192	1
224	1

----------PASS 3

N	VTC
104	1
112	1
120	1
128	1
136	1
144	1
152	1

----------PASS 4

N	VTC
122	1
124	1
126	1
128	1
130	1
132	1
134	1

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 128

ACTUAL VTC PEAK OCCURRED AT N = 306

ERROR FROM CORRECT N IS: ^178

QSET2 A606D

----------PASS 1

N	VTC
192	1
256	1
320	145
384	0
448	0
512	0
576	0

----------PASS 2

N	VTC
272	1
288	1
304	218
320	145
336	25
352	1
368	0

----------PASS 3

N	VTC
292	3
296	26
300	97
304	218
308	200
312	155
316	182

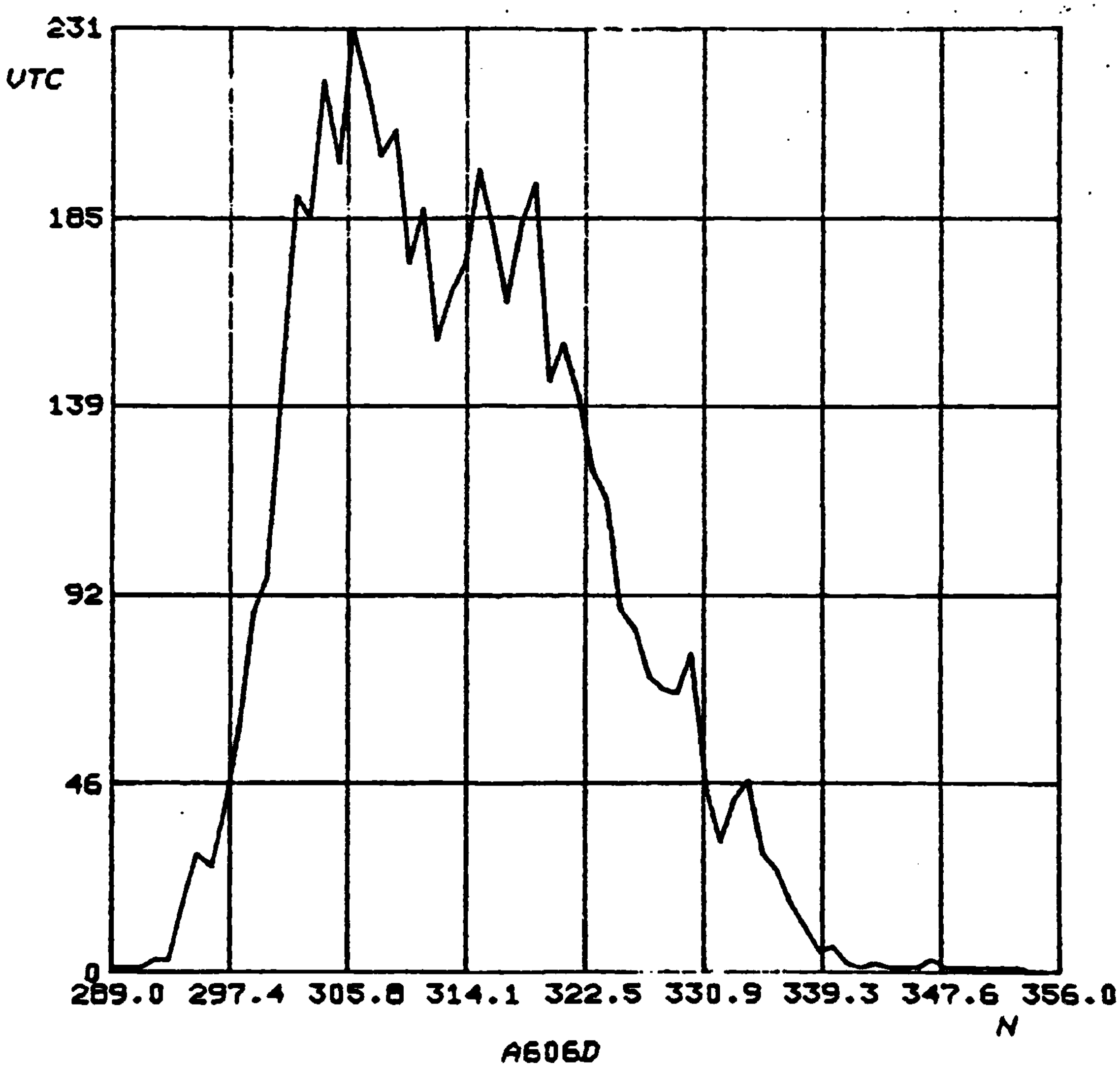
----------PASS 4

N	VTC
301	146
302	190
303	185
304	218
305	198
306	231
307	217

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 306

ACTUAL VTC PEAK OCCURRED AT N = 306

ERROR FROM CORRECT N IS: 0


231
VTC
185
139
92
46
0
289.0
297.4
305.8
314.1
322.5
330.9
339.3
347.6
356.0
N
A606D

QSET1 A6071

----------PASS 1

N	VTC
128	1
256	1
384	120
512	41
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	4
352	67
384	120
416	199
448	157
480	101

----------PASS 3

N	VTC
392	144
400	179
408	193
416	199
424	190
432	176
440	163

----------PASS 4

N	VTC
410	204
412	204
414	208
416	199
418	204
420	200
422	187

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 414

ACTUAL VTC PEAK OCCURRED AT N = 414

ERROR FROM CORRECT N IS: 0

QSET2 A6071

----------PASS 1

N	VTC
192	1
256	1
320	4
384	120
448	157
512	41
576	0

----------PASS 2

N	VTC
400	179
416	199
432	176
448	157
464	132
480	101
496	75

----------PASS 3

N	VTC
404	190
408	193
412	204
416	199
420	200
424	190
428	182

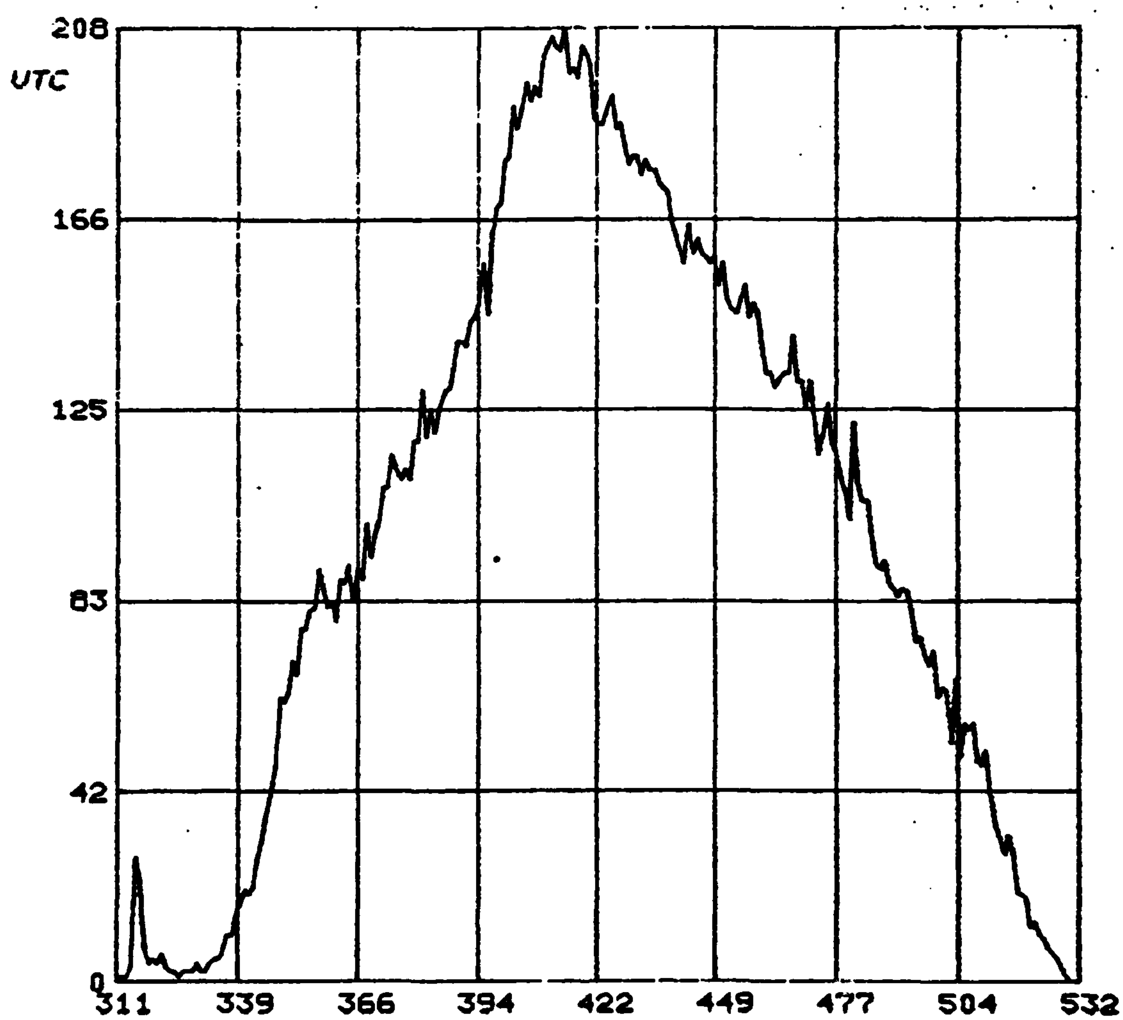
----------PASS 4

N	VTC
409	202
410	204
411	206
412	204
413	203
414	208
415	198

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 414

ACTUAL VTC PEAK OCCURRED AT N = 414

ERROR FROM CORRECT N IS: 0



A6071

QSET1 A6072

----------PASS 1

N	VTC
128	1
256	1
384	160
512	13
640	0
768	0
896	0

----------PASS 2

N	VTC
288	5
320	4
352	85
384	160
416	191
448	148
480	84

----------PASS 3

N	VTC
392	188
400	190
408	199
416	191
424	180
432	169
440	156

----------PASS 4

N	VTC
402	200
404	196
406	201
408	199
410	192
412	186
414	190

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 406

ACTUAL VTC PEAK OCCURRED AT N = 398

ERROR FROM CORRECT N IS: 8

QSET
QSET2 A6072

----------PASS 1

N	VTC
192	1
256	1
320	4
384	160
448	148
512	13
576	0

----------PASS 2

N	VTC
336	46
352	85
368	113
384	160
400	190
416	191
432	169

----------PASS 3

N	VTC
404	196
408	199
412	186
416	191
420	179
424	180
428	176

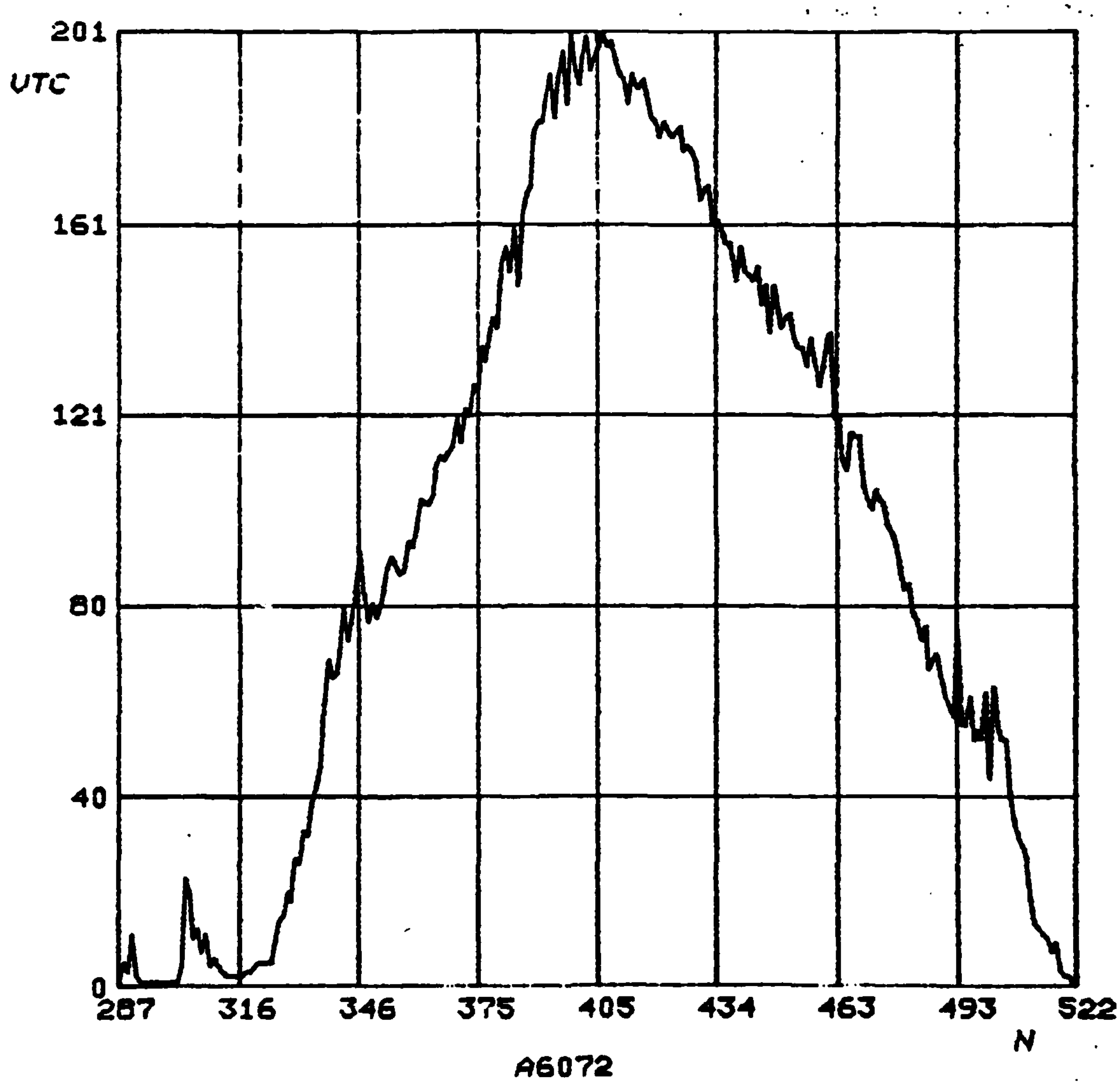
----------PASS 4

N	VTC
405	198
406	201
407	198
408	199
409	195
410	192
411	191

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 406

ACTUAL VTC PEAK OCCURRED AT N = 398

ERROR FROM CORRECT N IS: 8


201
UTC
161
121
80
40
0
287
316
346
375
405
434
463
493
522
N
A6072

QSET1 A6073

----------PASS 1

N	VTC
128	1
256	1
384	169
512	7
640	0
768	0
896	0

----------PASS 2

N	VTC
288	2
320	6
352	87
384	169
416	185
448	140
480	75

----------PASS 3

N	VTC
392	196
400	197
408	197
416	185
424	170
432	154
440	149

----------PASS 4

N	VTC
394	192
396	195
398	189
400	197
402	196
404	194
406	192

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 400

ACTUAL VTC PEAK OCCURRED AT N = 401

ERROR FROM CORRECT N IS: ^1

QSET2 A6073

----------PASS 1

N	VTC
192	1
256	1
320	6
384	169
448	140
512	7
576	0

----------PASS 2

N	VTC
336	68
352	87
368	123
384	169
400	197
416	185
432	154

----------PASS 3

N	VTC
388	193
392	196
396	195
400	197
404	194
408	197
412	184

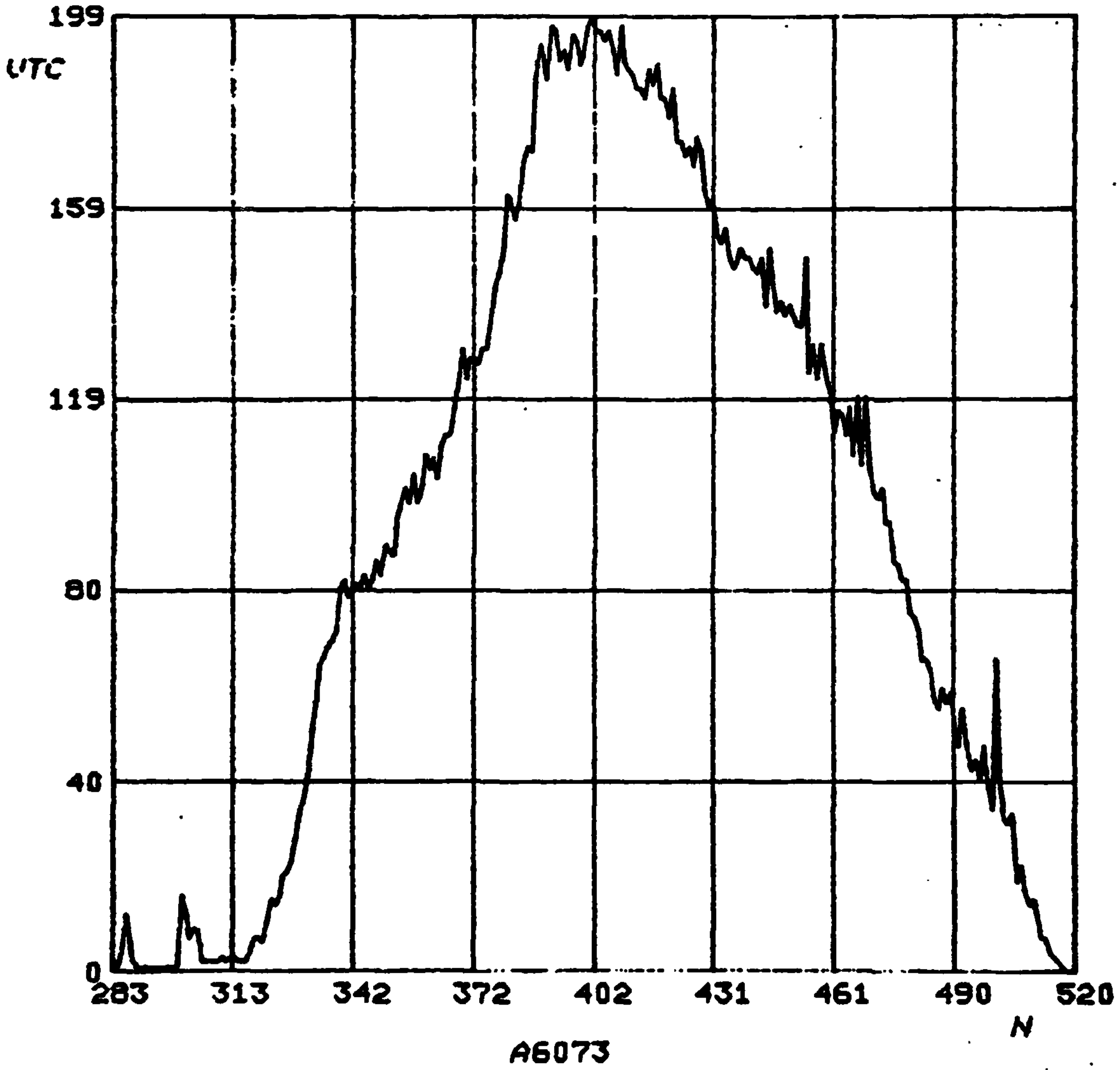
----------PASS 4

N	VTC
397	194
398	189
399	192
400	197
401	199
402	196
403	196

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 401

ACTUAL VTC PEAK OCCURRED AT N = 401

ERROR FROM CORRECT N IS: 0


199
UTC
159
119
80
40
0
283
313
342
372
402
431
461
490
520
N
A6073

QSET1 A6074

----------PASS 1

N	VTC
128	1
256	1
384	163
512	3
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	8
352	103
384	163
416	184
448	138
480	65

----------PASS 3

N	VTC
392	201
400	199
408	185
416	184
424	158
432	162
440	143

----------PASS 4

N	VTC
386	167
388	185
390	185
392	201
394	193
396	194
398	192

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 392

ACTUAL VTC PEAK OCCURRED AT N = 392

ERROR FROM CORRECT N IS: 0

QSET2 A6074

----------PASS 1

N	VTC
192	1
256	1
320	8
384	163
448	138
512	3
576	0

----------PASS 2

N	VTC
336	63
352	103
368	120
384	163
400	199
416	184
432	162

----------PASS 3

N	VTC
388	185
392	201
396	194
400	199
404	189
408	185
412	189

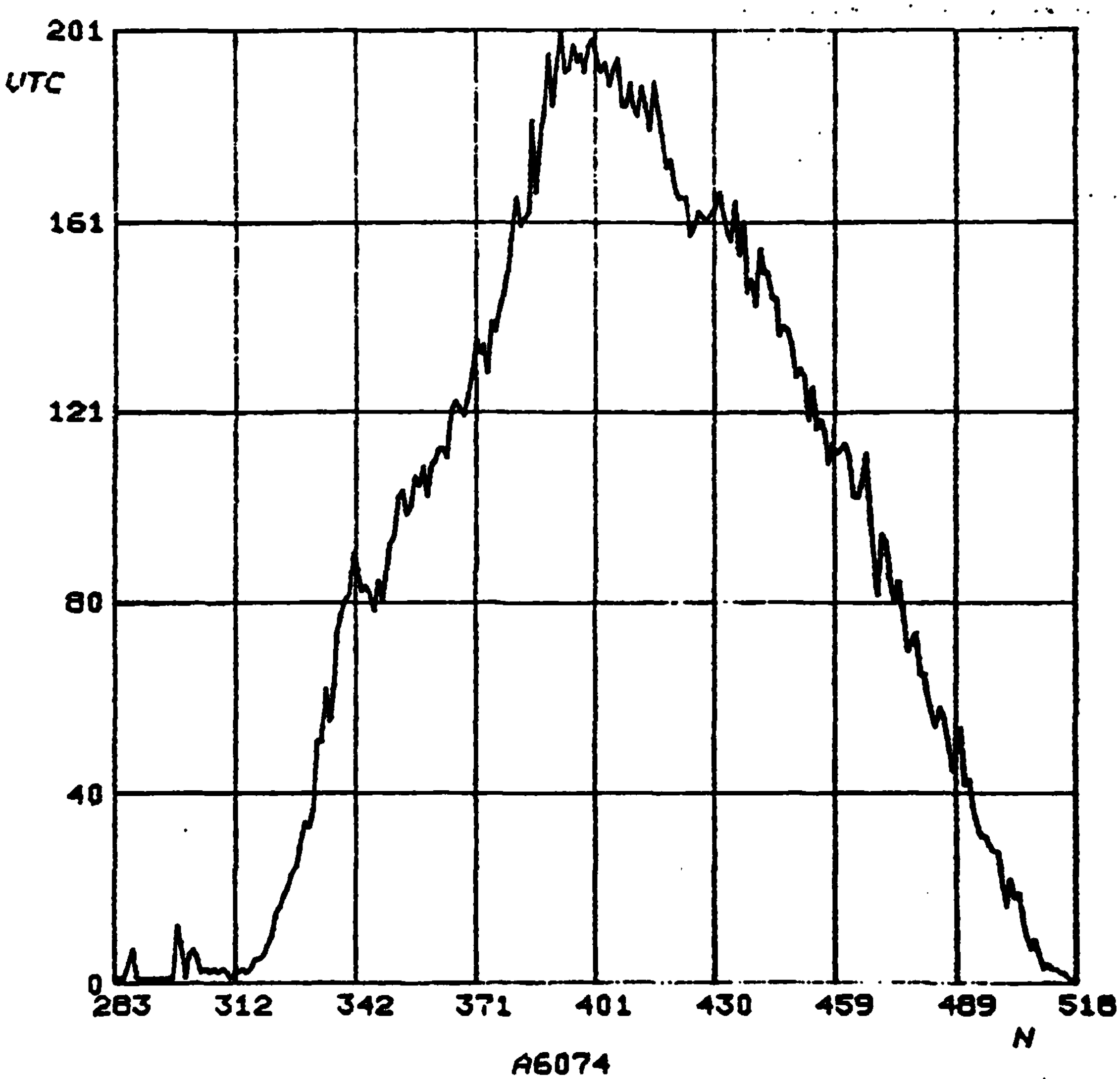
----------PASS 4

N	VTC
389	196
390	185
391	193
392	201
393	192
394	193
395	198

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 392

ACTUAL VTC PEAK OCCURRED AT N = 392

ERROR FROM CORRECT N IS: 0


201
UTC
161
121
80
40
0
283
312
342
371
401
430
459
489
518
N
A6074

QSET1 A6075

----------PASS 1

N	VTC
128	1
256	1
384	147
512	41
640	0
768	0
896	0

----------PASS 2

N	VTC
288	3
320	7
352	81
384	147
416	190
448	146
480	101

----------PASS 3

N	VTC
392	182
400	190
408	191
416	190
424	177
432	173
440	153

----------PASS 4

N	VTC
402	202
404	204
406	197
408	191
410	203
412	202
414	196

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 404

ACTUAL VTC PEAK OCCURRED AT N = 403

ERROR FROM CORRECT N IS: 1

QSET2 A6075

----------PASS 1

N	VTC
192	1
256	1
320	7
384	147
448	146
512	41
576	0

----------PASS 2

N	VTC
336	63
352	81
368	115
384	147
400	190
416	190
432	173

----------PASS 3

N	VTC
388	161
392	182
396	190
400	190
404	204
408	191
412	202

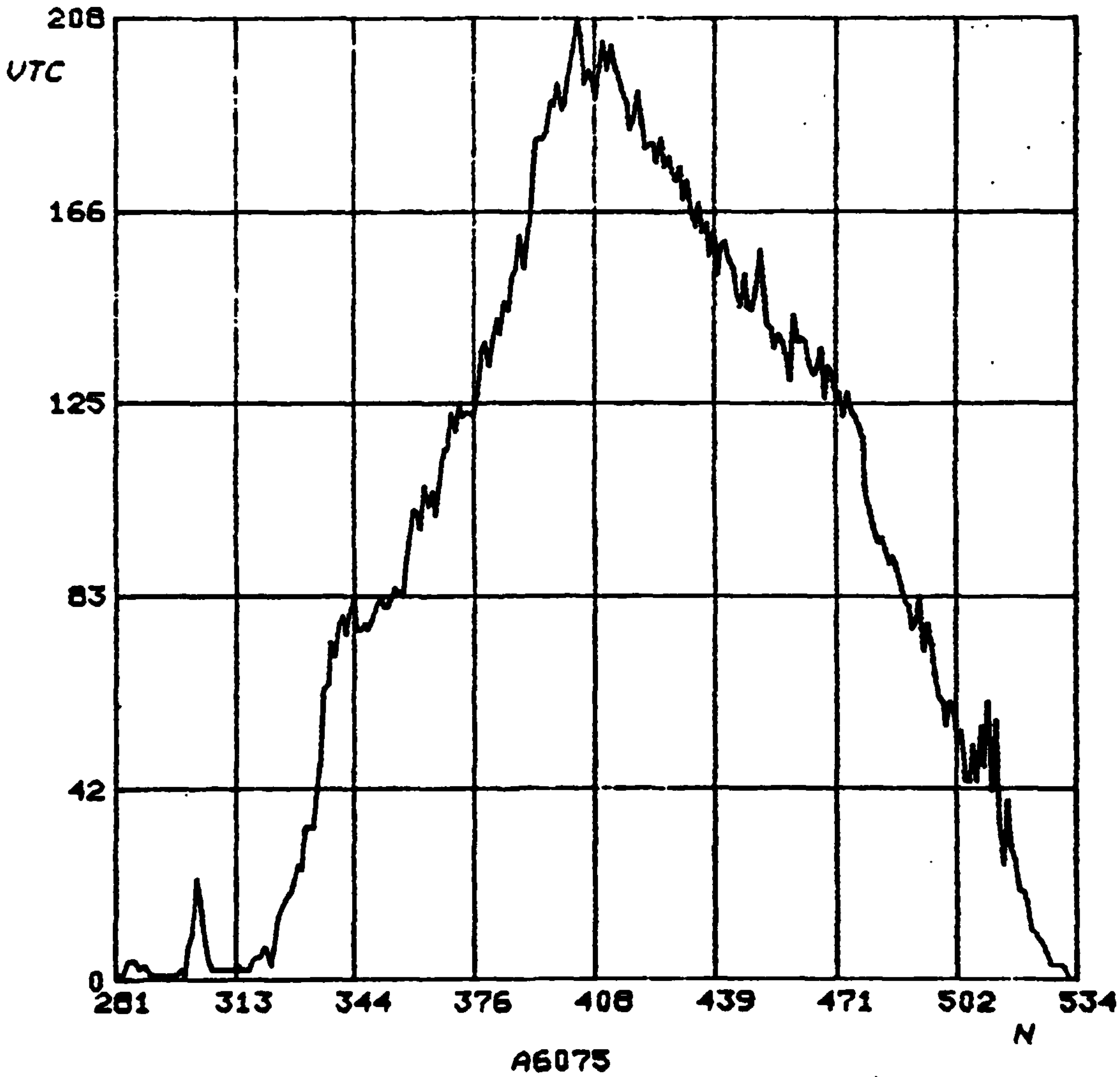
----------PASS 4

N	VTC
401	197
402	202
403	208
404	204
405	194
406	197
407	195

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 403

ACTUAL VTC PEAK OCCURRED AT N = 403

ERROR FROM CORRECT N IS: 0


208
UTC
166
125
83
42
0
281
313
344
376
408
439
471
502
534
N
A6075

QSET1 B6062

----------PASS 1

N	VTC
128	1
256	1
384	400
512	3
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	151
352	416
384	400
416	384
448	366
480	81

----------PASS 3

N	VTC
328	260
336	428
344	437
352	416
360	406
368	405
376	395

----------PASS 4

N	VTC
338	438
340	437
342	452
344	437
346	432
348	424
350	420

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 342

ACTUAL VTC PEAK OCCURRED AT N = 343

ERROR FROM CORRECT N IS: ^1

QSET2 B6062

----------PASS 1

N	VTC
192	1
256	1
320	151
384	400
448	366
512	3
576	0

----------PASS 2

N	VTC
336	428
352	416
368	405
384	400
400	400
416	384
432	387

----------PASS 3

N	VTC
324	213
328	260
332	360
336	428
340	437
344	437
348	424

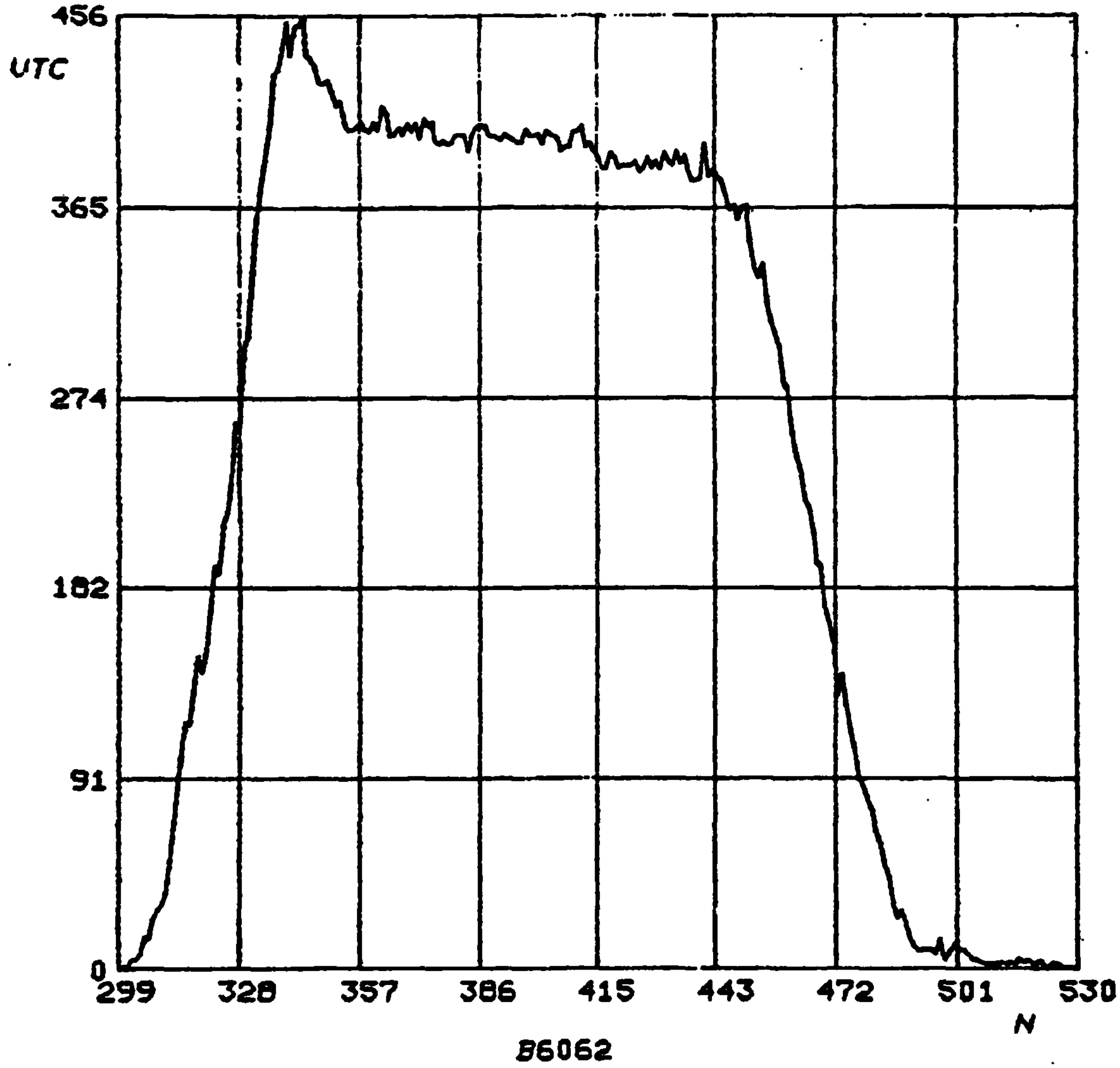
----------PASS 4

N	VTC
337	430
338	438
339	453
340	437
341	451
342	452
343	456

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 343

ACTUAL VTC PEAK OCCURRED AT N = 343

ERROR FROM CORRECT N IS: 0


456
UTC
365
274
182
91
0
299
328
357
386
415
443
472
501
530
N
B6062

QSET1 C6062

----------PASS 1

N	VTC
128	1
256	1
384	210
512	58
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	255
352	212
384	210
416	205
448	213
480	194

----------PASS 3

N	VTC
296	12
304	97
312	219
320	255
328	242
336	220
344	223

----------PASS 4

N	VTC
314	231
316	261
318	259
320	255
322	253
324	243
326	237

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 316

ACTUAL VTC PEAK OCCURRED AT N = 316

ERROR FROM CORRECT N IS: 0

QSET2 C6062

----------PASS 1

N	VTC
192	1
256	1
320	255
384	210
448	213
512	58
576	0

----------PASS 2

N	VTC
272	1
288	1
304	97
320	255
336	220
352	212
368	213

----------PASS 3

N	VTC
308	144
312	219
316	261
320	255
324	243
328	242
332	234

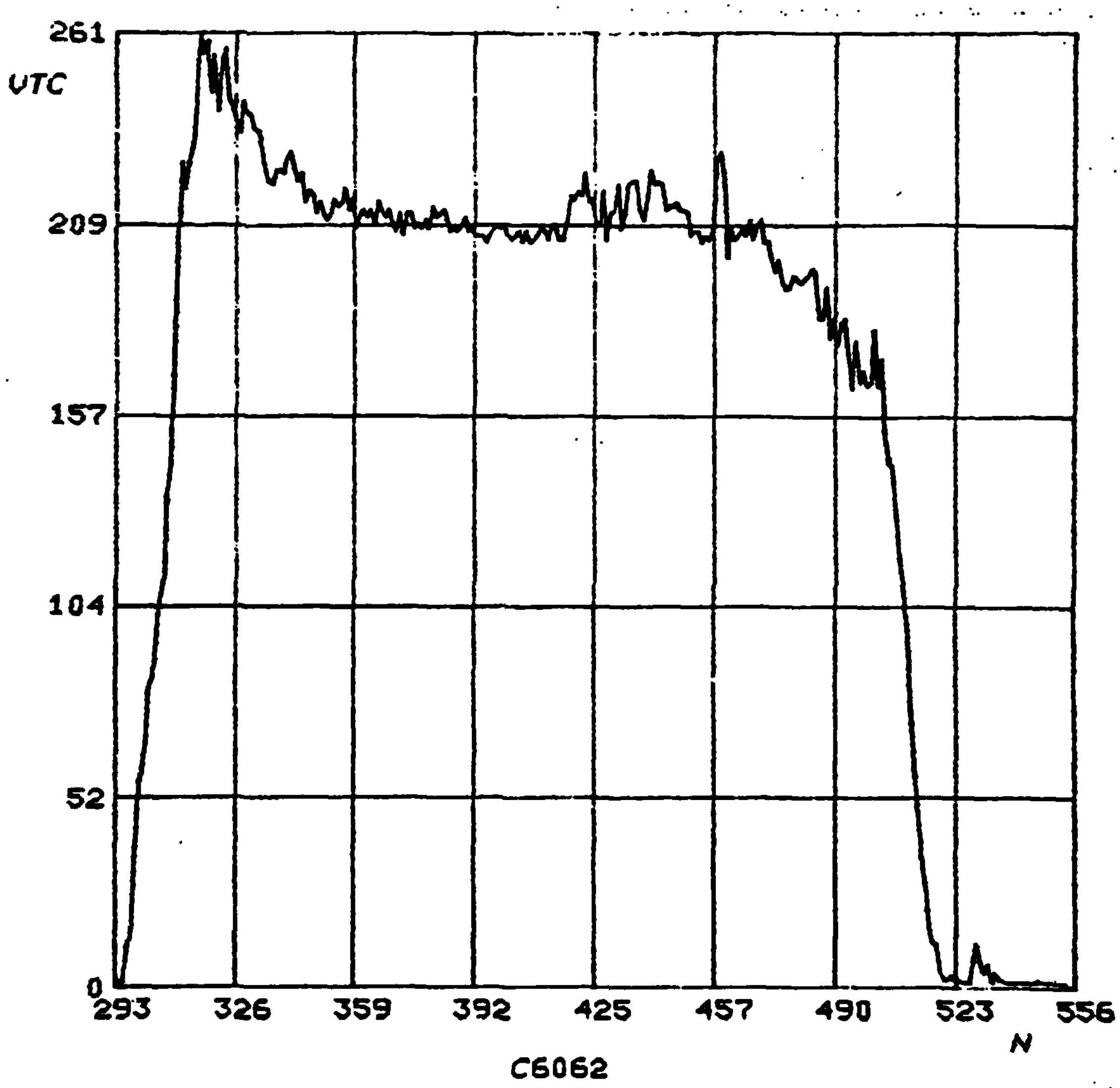
----------PASS 4

N	VTC
313	226
314	231
315	240
316	261
317	255
318	259
319	245

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 316

ACTUAL VTC PEAK OCCURRED AT N = 316

ERROR FROM CORRECT N IS: 0


261
VTC
209
157
104
52
0
293
326
359
392
425
457
490
523
556
N
C6062

QSET1 D6062

----------PASS 1

N	VTC
128	1
256	1
384	43
512	58
640	0
768	0
896	0

----------PASS 2

N	VTC
416	46
448	46
480	49
512	58
544	0
576	0
608	0

----------PASS 3

N	VTC
488	51
496	50
504	53
512	58
520	60
528	46
536	31

----------PASS 4

N	VTC
514	45
516	57
518	71
520	60
522	72
524	80
526	53

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 524

ACTUAL VTC PEAK OCCURRED AT N = 524

ERROR FROM CORRECT N IS: 0

QSET2 D6062

----------PASS 1

N	VTC
192	1
256	1
320	53
384	43
448	46
512	58
576	0

----------PASS 2

N	VTC
464	58
480	49
496	50
512	58
528	46
544	0
560	0

----------PASS 3

N	VTC
500	46
504	53
508	51
512	58
516	57
520	60
524	80

----------PASS 4

N	VTC
521	65
522	72
523	75
524	80
525	55
526	53
527	49

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 524

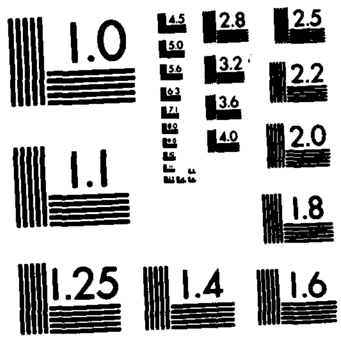
ACTUAL VTC PEAK OCCURRED AT N = 524

ERROR FROM CORRECT N IS: 0

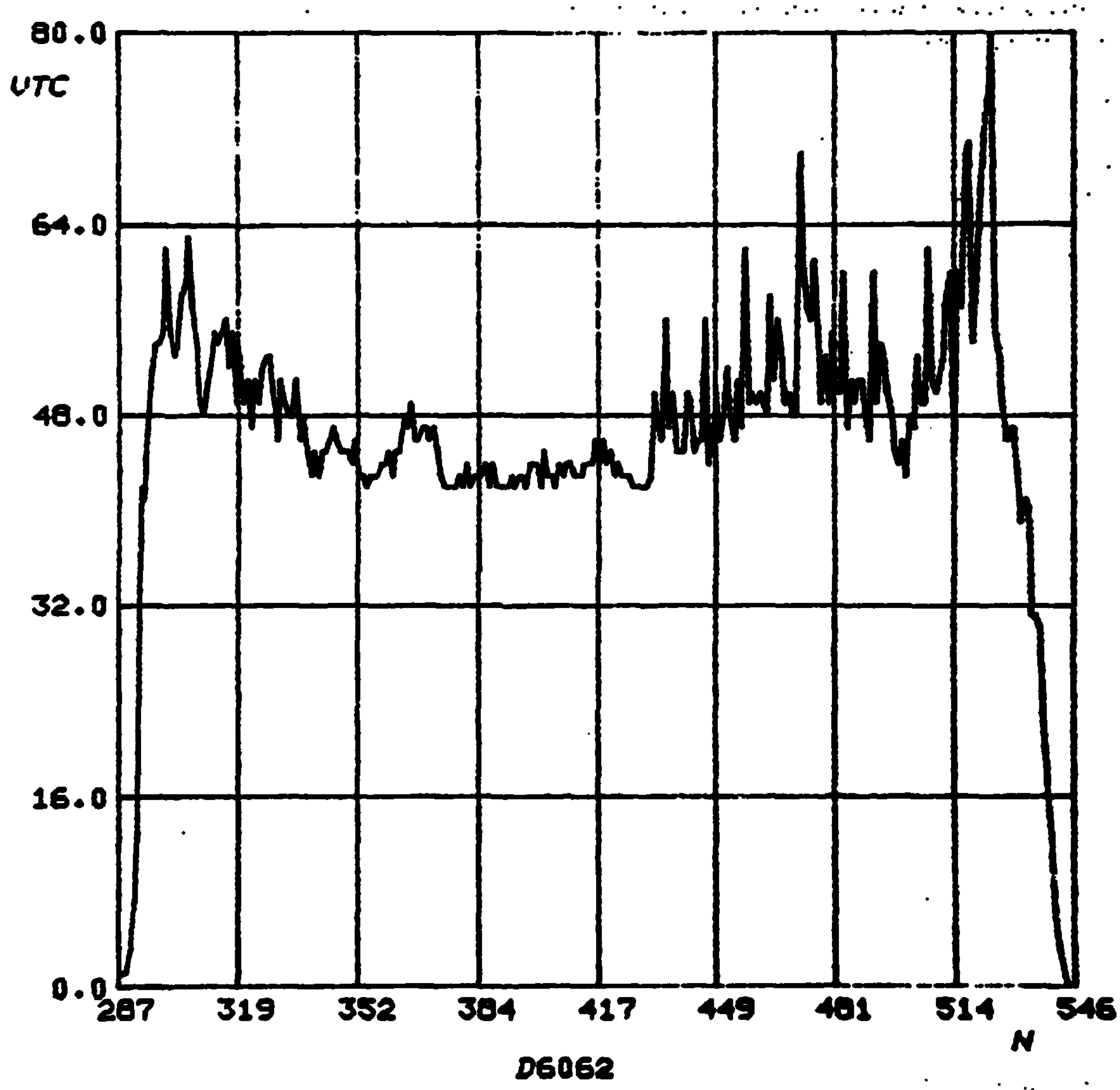
AD-A125 316 AUTOMATIC THRESHOLD DESIGN FOR A BOUND DOCUMENT SCANNER 3/3
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH
B J STANTON DEC 82 AFIT-CI/NR-82-71T

UNCLASSIFIED F/G 17/2 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



80.0
UTC
64.0
48.0
32.0
16.0
0.0
287
319
352
384
417
449
481
514
546
N
D6062

QSET1 E6062

----------PASS 1

N	VTC
128	1
256	1
384	83
512	94
640	0
768	0
896	0

----------PASS 2

N	VTC
416	86
448	90
480	86
512	94
544	79
576	28
608	0

----------PASS 3

N	VTC
488	91
496	86
504	83
512	94
520	82
528	84
536	90

----------PASS 4

N	VTC
506	95
508	87
510	86
512	94
514	85
516	84
518	83

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 506

ACTUAL VTC PEAK OCCURRED AT N = 429

ERROR FROM CORRECT N IS: 77

QSET2 E6062

----------PASS 1

N	VTC
192	1
256	1
320	17
384	83
448	90
512	94
576	28

----------PASS 2

N	VTC
464	86
480	86
496	86
512	94
528	84
544	79
560	83

----------PASS 3

N	VTC
500	90
504	83
508	87
512	94
516	84
520	82
524	79

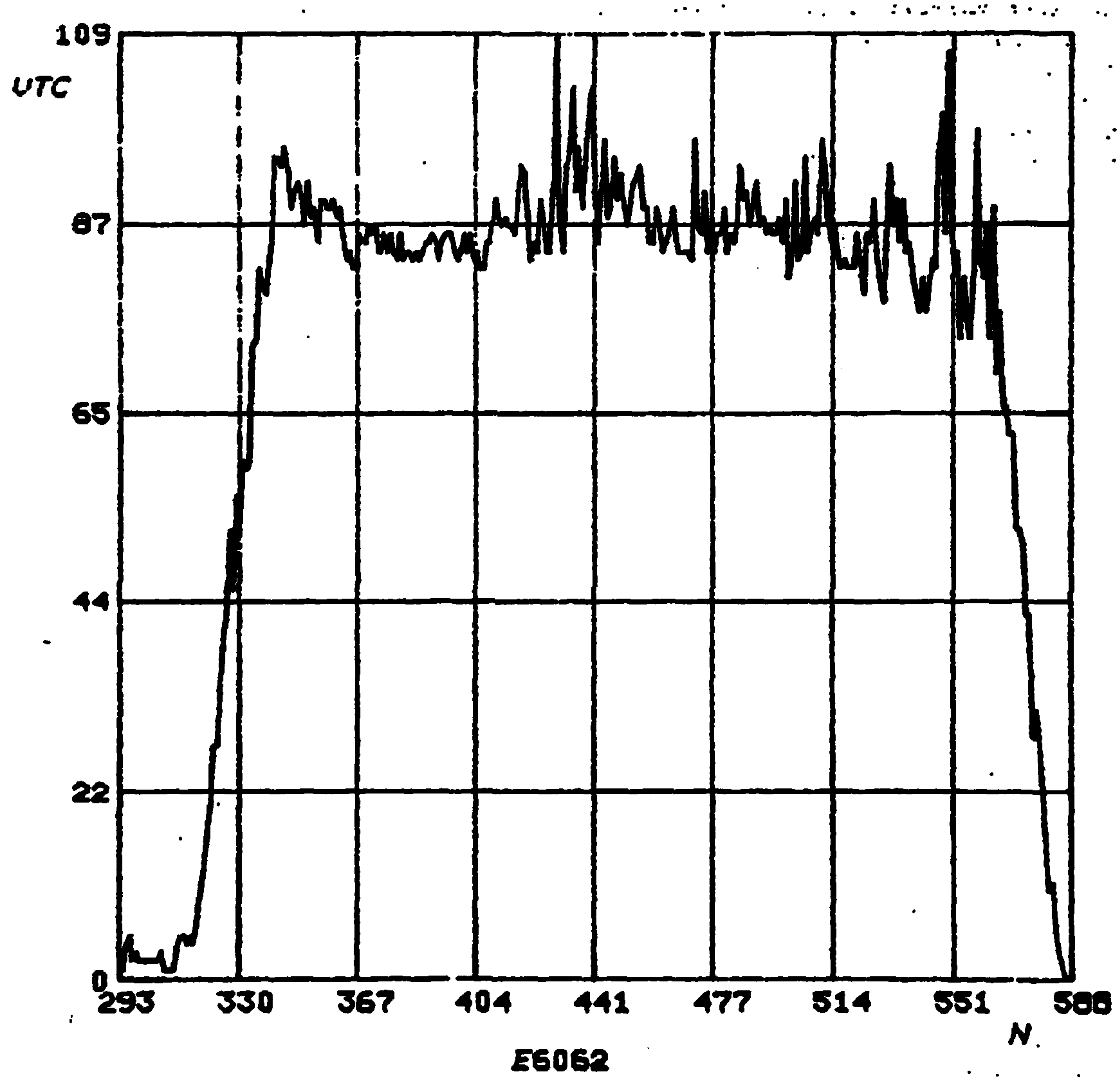
----------PASS 4

N	VTC
509	88
510	86
511	97
512	94
513	88
514	85
515	87

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 511

ACTUAL VTC PEAK OCCURRED AT N = 429

ERROR FROM CORRECT N IS: 82


109
UTC
87
65
44
22
0
293
330
367
404
441
477
514
551
588
N
E6062

QSET1 F6062

----------PASS 1

N	VTC
128	1
256	1
384	39
512	50
640	5
768	0
896	0

----------PASS 2

N	VTC
416	56
448	58
480	57
512	50
544	41
576	31
608	17

----------PASS 3

N	VTC
424	62
432	58
440	62
448	58
456	55
464	56
472	62

----------PASS 4

N	VTC
418	58
420	62
422	61
424	62
426	59
428	56
430	58

ACCORDING TO QSET1, THE THRESHOLD VALUE PRODUCING THE PEAK OF THE VTC CURVE IS N = 424

ACTUAL VTC PEAK OCCURRED AT N = 469

ERROR FROM CORRECT N IS: ^45

QSET2 F6062

----------PASS 1

N	VTC
192	1
256	1
320	23
384	39
448	58
512	50
576	31

----------PASS 2

N	VTC
400	47
416	56
432	58
448	58
464	56
480	57
496	59

----------PASS 3

N	VTC
484	55
488	54
492	54
496	59
500	61
504	56
508	53

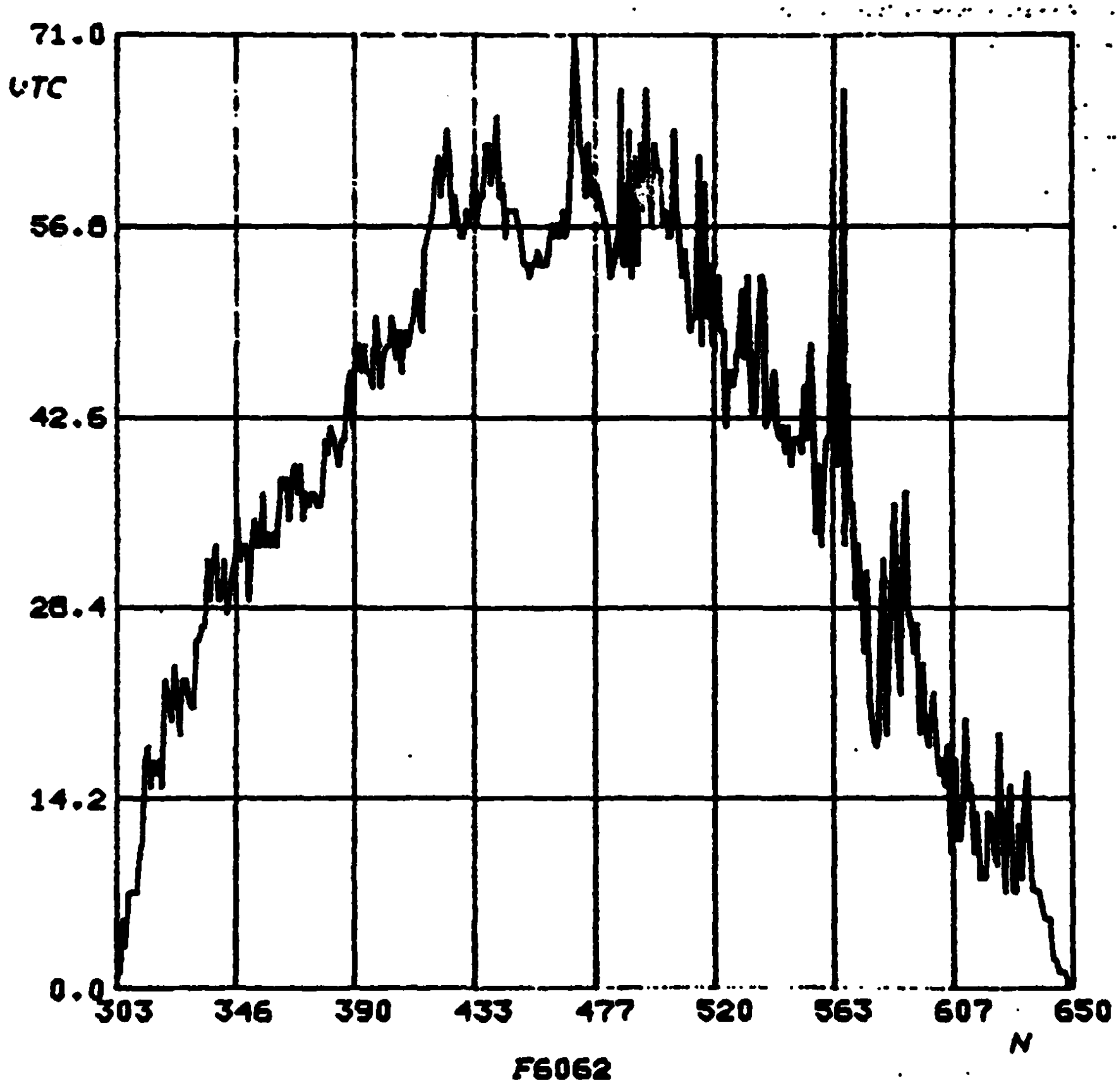
----------PASS 4

N	VTC
497	57
498	63
499	61
500	61
501	57
502	58
503	56

ACCORDING TO QSET2, THE THRESHOLD VALUE PRODUCING THE PEAK OF THE VTC CURVE IS N = 498

ACTUAL VTC PEAK OCCURRED AT N = 469

ERROR FROM CORRECT N IS: 29


71.0
UTC
56.8
42.6
28.4
14.2
0.0
303
346
390
433
477
520
563
607
650
N
F6062

QSET1 A6231			QSET2 A6231	
----------PASS 1			----------PASS 1	
N	VTC		N	VTC
128	1		192	1
256	1		256	1
384	155		320	52
512	129		384	155
640	0		448	170
768	0		512	129
896	0		576	4
----------PASS 2			----------PASS 2	
N	VTC		N	VTC
288	1		400	186
320	52		416	195
352	102		432	186
384	155		448	170
416	195		464	163
448	170		480	146
480	146		496	151
----------PASS 3			----------PASS 3	
N	VTC		N	VTC
392	169		404	192
400	186		408	193
408	193		412	189
416	195		416	195
424	195		420	198
432	186		424	195
440	178		428	193
----------PASS 4			----------PASS 4	
N	VTC		N	VTC
410	190		417	192
412	189		418	197
414	191		419	195
416	195		420	198
418	197		421	195
420	198		422	194
422	194		423	194

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 420

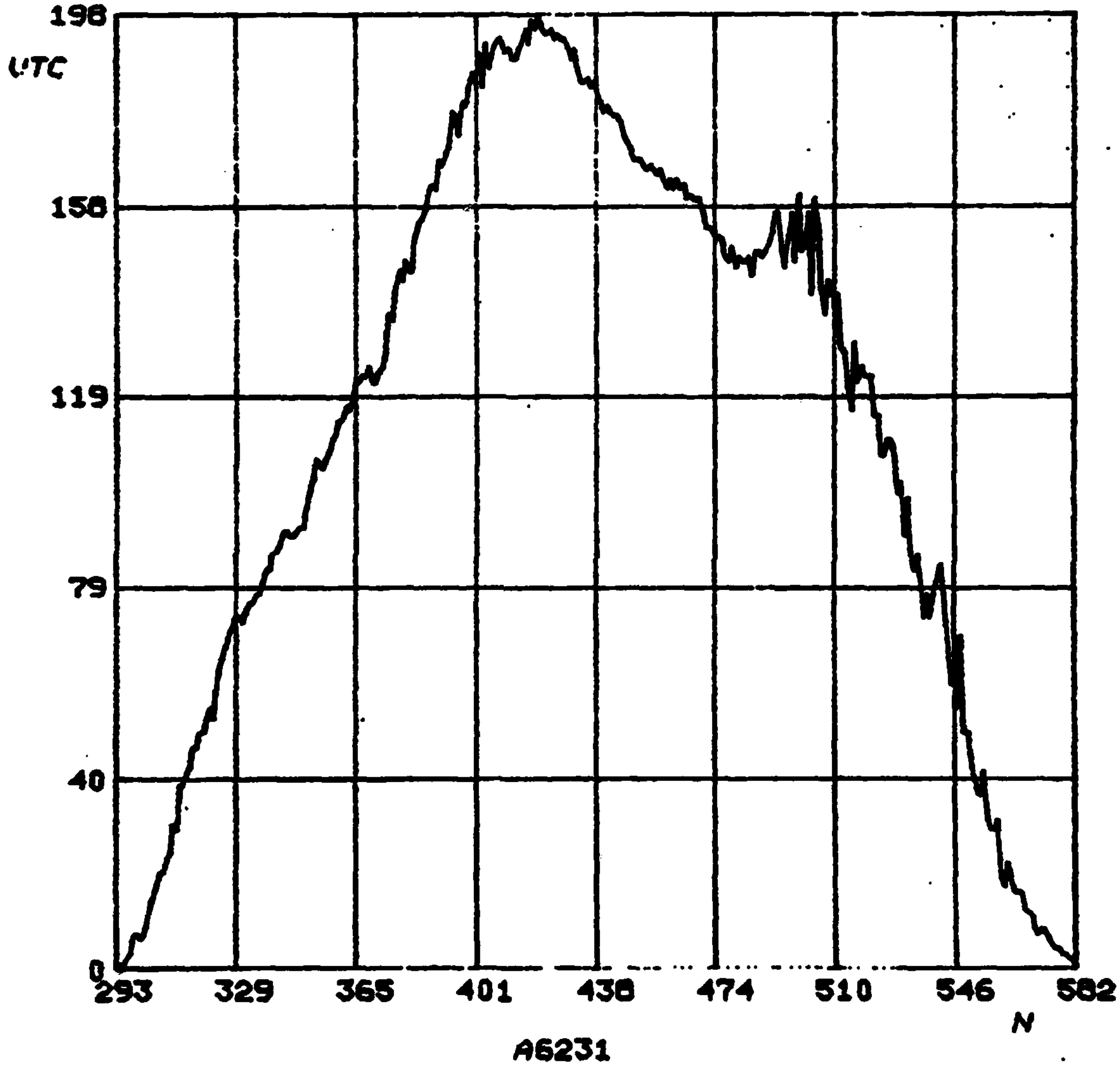
ACTUAL VTC PEAK OCCURRED AT N = 420

ERROR FROM CORRECT N IS: 0

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 420

ACTUAL VTC PEAK OCCURRED AT N = 420

ERROR FROM CORRECT N IS: 0


198
UTC
158
119
79
40
0
293
329
365
401
438
474
510
546
582
N
A6231

QSET1 A6232

----------PASS 1

N	VTC
128	1
256	1
384	153
512	101
640	0
768	0
896	0

----------PASS 2

N	VTC
288	1
320	46
352	91
384	153
416	178
448	169
480	153

----------PASS 3

N	VTC
392	157
400	166
408	177
416	178
424	181
432	175
440	167

----------PASS 4

N	VTC
418	174
420	173
422	178
424	181
426	182
428	177
430	174

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 426

ACTUAL VTC PEAK OCCURRED AT N = 452

ERROR FROM CORRECT N IS: ^26

QSET2 A6232

----------PASS 1

N	VTC
192	1
256	1
320	46
384	153
448	169
512	101
576	9

----------PASS 2

N	VTC
400	166
416	178
432	175
448	169
464	173
480	153
496	123

----------PASS 3

N	VTC
404	169
408	177
412	179
416	178
420	173
424	181
428	177

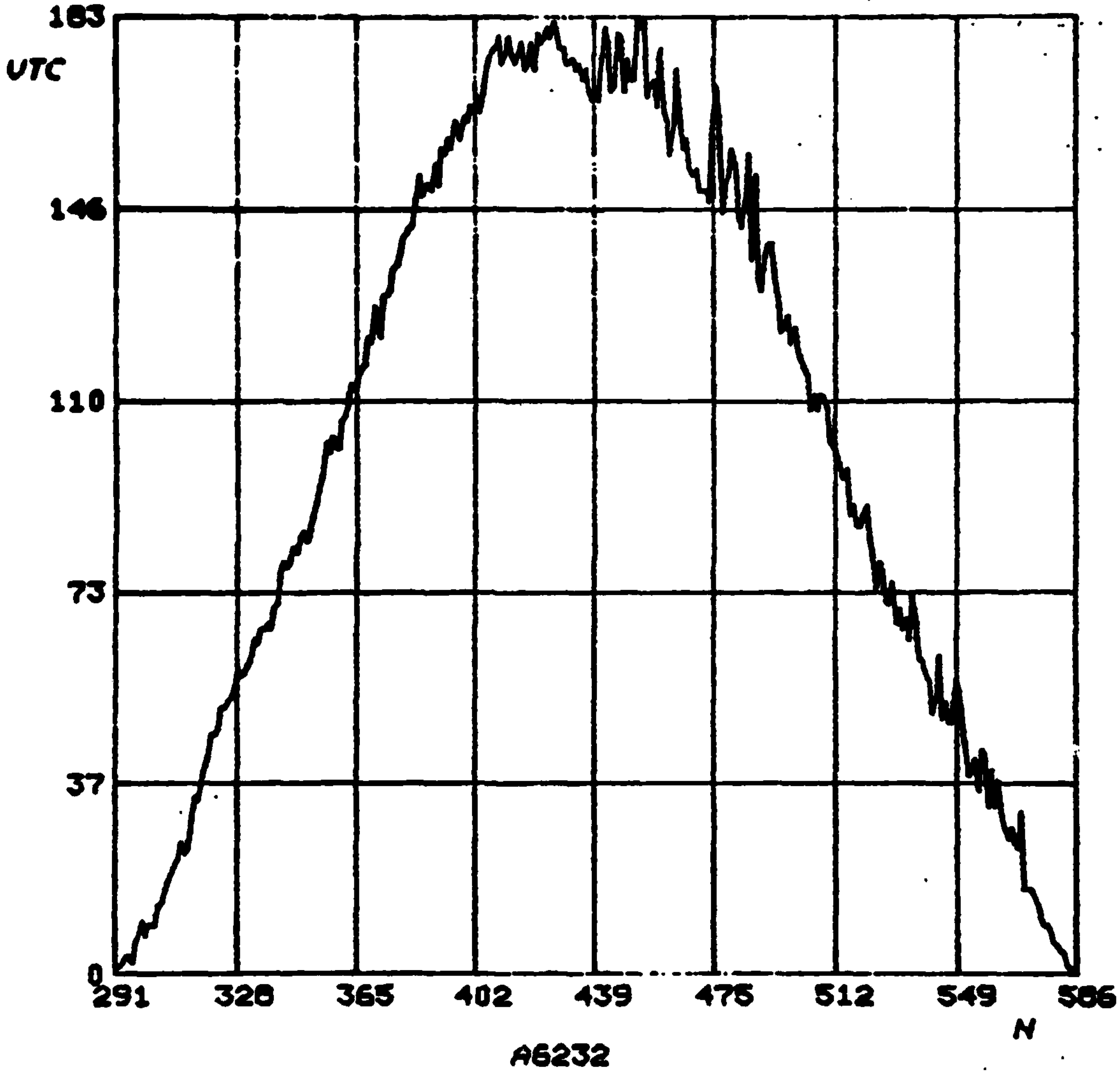
----------PASS 4

N	VTC
421	180
422	178
423	179
424	181
425	179
426	182
427	180

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 426

ACTUAL VTC PEAK OCCURRED AT N = 452

ERROR FROM CORRECT N IS: ^26


183
UTC
146
110
73
37
0
291
328
365
402
439
475
512
549
586
N
A6232

QSET1 A6233

----------PASS 1

N	VTC
128	1
256	1
384	114
512	136
640	0
768	0
896	0

----------PASS 2

N	VTC
416	182
448	178
480	156
512	136
544	105
576	49
608	2

----------PASS 3

N	VTC
392	139
400	149
408	156
416	182
424	200
432	190
440	188

----------PASS 4

N	VTC
418	184
420	186
422	183
424	200
426	192
428	191
430	196

ACCORDING TO QSET1, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 424

ACTUAL VTC PEAK OCCURRED AT N = 423

ERROR FROM CORRECT N IS: 1

QSET2 A6233

----------PASS 1

N	VTC
192	1
256	1
320	19
384	114
448	178
512	136
576	49

----------PASS 2

N	VTC
400	149
416	182
432	190
448	178
464	172
480	156
496	149

----------PASS 3

N	VTC
420	186
424	200
428	191
432	190
436	193
440	188
444	184

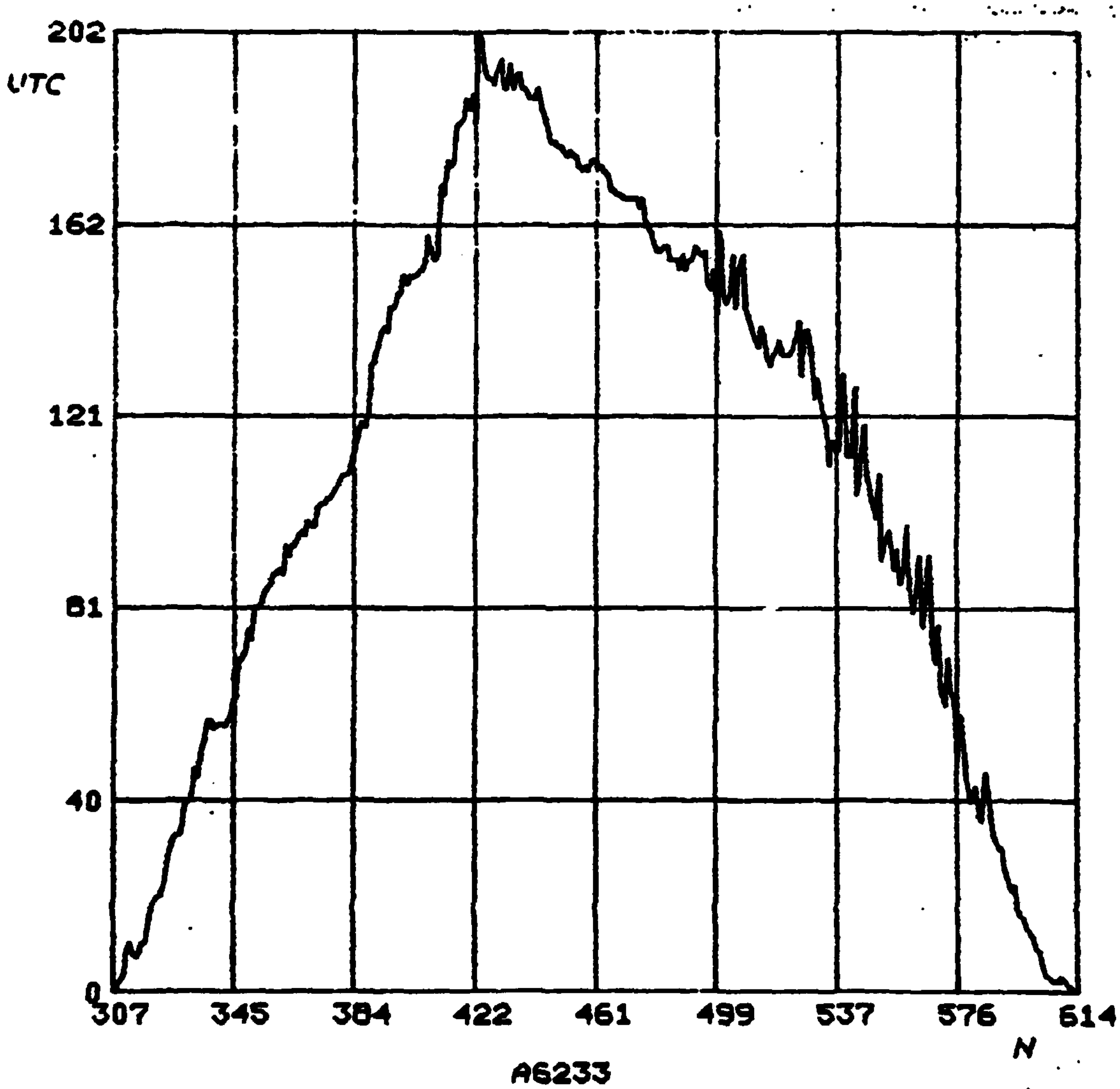
----------PASS 4

N	VTC
421	189
422	183
423	202
424	200
425	194
426	192
427	192

ACCORDING TO QSET2, THE
THRESHOLD VALUE PRODUCING
THE PEAK OF THE VTC CURVE IS N = 423

ACTUAL VTC PEAK OCCURRED AT N = 423

ERROR FROM CORRECT N IS: 0


202
UTC
162
121
81
40
0
307
345
384
422
461
499
537
576
614
N
A6233

APPENDIX D

DATA SET TRANSFER AND PLOTTING

The purpose of this appendix is to document the procedure for gathering VTC-versus-N data and transferring it to the Multics Computing System for analysis. Included are the source codes and explanations for the software used with the F8 microprocessor and with the Multics Graphics System.

To analyze the VTC curve for a particular set of conditions, the first step is to prepare the scanner for gathering a data set by loading and running the software package PLOT4 with Sense Switches 4, 5, and 6 in the DOWN position. (The Sense Switches are located on the front panel of the F8). With the Experimental Calibration Pattern (ECP) ready, the scanner start button should be pressed to initiate the page-scanning sequence. Once the moving assembly is approximately mid-page, the scanner should be frozen in position with the Crossfeed-Motor Pause Switch. Now, by referencing the shape of the analog video signal with an oscilloscope, the ECP to be scanned can be placed into position. VTC data are taken and stored in the F8 RAM memory when Sense 5 is placed to the UP position. Since PLOT4 gathers VTC data for every value of N from N = 0 to N = 768, it will take about three seconds from the time Sense 5 is activated until all data have been stored. The status of the lights on the front panel of the F8 will indicate when data transfer is complete. (Note that it is a simple software modification to alter the sampling range of

N if necessary.) At this point, if one is satisfied with the conditions under which the data was taken, Sense 4 can be placed UP which will terminate the PLOT4 routine. Otherwise PLOT4 can be recycled by first placing Sense 5 DOWN and then momentarily placing Sense 6 UP and then DOWN.

By resetting PLOT4, this enables the user to overwrite the original set of data with new data.

The next step is to enter the F8 DEBUG program to gain access to the data set that is now stored in RAM. The data buffer begins at memory location 0100(HEX), but significant data normally starts between 0500(HEX) and 0600(HEX). The data can be examined in BYTE form by using the DIM (display memory) command described in the F8 manuals. Values of N and VTC each require two bytes, and N-VTC data pairs are stored consecutively. As an example, data displayed by the command, DIM 0910-0A7F are shown in Figure D.1. To minimize the amount of storage and Multics computer time required, the bounds of significant VTC data should be ascertained before transferring any information out of RAM.

With the bounds of the data determined, the next step is to write the data into an F8 disk file for permanent storage and ease of manipulation. While still in the DEBUG program, the following sequence of commands will accomplish this:

```
MON
ASS CR WDISK <filename>,00:1
DEBUG
DIM <starting RAM address>-<ending RAM address>
MON
ASS CR ZTO
```

The data set is now in the form of an ASCII file on disk. To transfer the data to the Multics System, the following commands must be added to the file by the XEDIT editor. Before the data, include these lines:

```
&version 2
&trace off
&attach
apl -ttp ASCII
input2
```

After the data, include these lines:

```
stop
&detach
&quit
```

The disk file should now appear like the example in Figure D.2.

The F8 program, MULTX, is used to transfer the disk file to a Multics storage segment via dial-up link. Since the data set is now set up as an exec file, the Multics segment name must have the .ec suffix, e.g. filename.ec. With the data in a segment, any of a number of options can be employed to convert the data from its ASCII format to a usable decimal equivalent. However, this author used APL language for data manipulations. The procedure therefore continues as such: An APL workspace named CONTINUE must be already established and contain as a minimum the functions INPUT2 and CONVERT whose listings and explanations are included in this appendix. With these prerequisites met, execute the data set segment with the Multics command,

```
ec filename
```

A terminal prompt message will indicate when data transfer is complete. Multics is now in the APL ASCII mode and the proper

conventions must be followed. To complete the data conversion, select an appropriate variable name for the data set and invoke the function, CONVERT:

VARIABLENAME <- CONVERT

VARIABLENAME becomes a two-dimensional array with each row representing an X-Y (or N-VTC) data pair. The various APL functions described in the remainder of this appendix can now be used to operate on the data as necessary. One note of caution concerning the plotting functions should be observed. ALWAYS link and unlink the Multics Graphics I/O at the Multics Command level, NEVER while within the APL mode. The commands to do this are,

```
setup_graphics     (sg)
remove_graphics    (rg)
```

The syntax associated with these commands should be reviewed in the Multics Users Manuals as necessary.

```
M0910 = 02 05 01 30 02 06 01 30
M0918 = 02 07 01 2C 02 08 01 2D
M0920 = 02 09 01 25 02 0A 01 24
M0928 = 02 0B 01 24 02 0C 01 25
M0930 = 02 0D 01 19 02 0E 01 19
M0938 = 02 0F 01 1D 02 10 01 19
M0940 = 02 11 01 1C 02 12 01 1C
M0948 = 02 13 01 19 02 14 01 15
M0950 = 02 15 01 14 02 16 01 14
M0958 = 02 17 01 11 02 18 01 0D
M0960 = 02 19 01 0D 02 1A 01 0D
M0968 = 02 1B 01 0C 02 1C 01 10
M0970 = 02 1D 01 05 02 1E 01 08
M0978 = 02 1F 01 08 02 20 00 FD
M0980 = 02 21 00 FD 02 22 00 FD
M0988 = 02 23 00 FD 02 24 00 F9
M0990 = 02 25 00 F9 02 26 00 F8
M0998 = 02 27 00 F4 02 28 00 EC
M09A0 = 02 29 00 F0 02 2A 00 EC
M09A8 = 02 2B 00 ED 02 2C 00 ED
M09B0 = 02 2D 00 EC 02 2E 00 E1
M09B8 = 02 2F 00 E0 02 30 00 E4
M09C0 = 02 31 00 E8 02 32 00 DD
M09C8 = 02 33 00 DD 02 34 00 DC
M09D0 = 02 35 00 E4 02 36 00 D9
M09D8 = 02 37 00 D8 02 38 00 D1
M09E0 = 02 39 00 D1 02 3A 00 D0
M09E8 = 02 3B 00 CC 02 3C 00 CD
M09F0 = 02 3D 00 C9 02 3E 00 C8
M09F8 = 02 3F 00 C5 02 40 00 C1
M0A00 = 02 41 00 C0 02 42 00 C0
M0A08 = 02 43 00 BC 02 44 00 BC
M0A10 = 02 45 00 BC 02 46 00 C1
M0A18 = 02 47 00 BC 02 48 00 B0
M0A20 = 02 49 00 AC 02 4A 00 AD
M0A28 = 02 4B 00 A8 02 4C 00 A5
M0A30 = 02 4D 00 A4 02 4E 00 98
M0A38 = 02 4F 00 98 02 50 00 94
M0A40 = 02 51 00 8D 02 52 00 8C
M0A48 = 02 53 00 8D 02 54 00 88
M0A50 = 02 55 00 8D 02 56 00 85
M0A58 = 02 57 00 80 02 58 00 89
M0A60 = 02 59 00 84 02 5A 00 84
M0A68 = 02 5B 00 7D 02 5C 00 7D
M0A70 = 02 5D 00 79 02 5E 00 78
M0A78 = 02 5F 00 74 02 60 00 75
```

FIGURE D.1 SAMPLE LISTING OF THE F8 DEBUG PROGRAM USING "DISPLAY MEMORY"

```
&version 2
&trace off
&attach
apl -ttp ASCII
input2
M05D8 = 01 37 00 01 01 38 00 01
M05E0 = 01 39 00 01 01 3A 00 03
M05E8 = 01 3B 00 1B 01 3C 00 16
M05F0 = 01 3D 00 07 01 3E 00 04
M05F8 = 01 3F 00 05 01 40 00 04
M0600 = 01 41 00 06 01 42 00 03
M0608 = 01 43 00 02 01 44 00 02
M0610 = 01 45 00 01 01 46 00 02
M0618 = 01 47 00 02 01 48 00 02
M0620 = 01 49 00 04 01 4A 00 02
M0628 = 01 4B 00 02 01 4C 00 04
M0630 = 01 4D 00 05 01 4E 00 05
M0638 = 01 4F 00 06 01 50 00 0A
M0640 = 01 51 00 0A 01 52 00 0F
M0648 = 01 53 00 11 01 54 00 14
M0650 = 01 55 00 13 01 56 00 15
M0658 = 01 57 00 1B 01 58 00 1F
M0660 = 01 59 00 24 01 5A 00 2A
M0668 = 01 5B 00 2F 01 5C 00 3E
M0670 = 01 5D 00 3D 01 5E 00 3F
M0678 = 01 5F 00 46 01 60 00 43
M0680 = 01 61 00 4D 01 62 00 4D
M0688 = 01 63 00 51 01 64 00 52
M0690 = 01 65 00 5A 01 66 00 56
M0698 = 01 67 00 52 01 68 00 53
M06A0 = 01 69 00 4F 01 6A 00 58
M06A8 = 01 6B 00 57 01 6C 00 5B
M06B0 = 01 6D 00 53 01 6E 00 5A
M06B8 = 01 6F 00 58 01 70 00 64
M06C0 = 01 71 00 5D 01 72 00 62
M06C8 = 01 73 00 65 01 74 00 6C
M06D0 = 01 75 00 6C 01 76 00 73
M06D8 = 01 77 00 70 01 78 00 6E
M06E0 = 01 79 00 70 01 7A 00 6E
M06E8 = 01 7B 00 76 01 7C 00 76
M06F0 = 01 7D 00 81 01 7E 00 77
M06F8 = 01 7F 00 7D 01 80 00 78
M0700 = 01 81 00 7D 01 82 00 81
M0708 = 01 83 00 82 01 84 00 86
M0710 = 01 85 00 8C 01 86 00 8C
M0718 = 01 87 00 8B 01 88 00 90
M0720 = 01 89 00 91 01 8A 00 94
M0728 = 01 8B 00 9D 01 8C 00 92
M0730 = 01 8D 00 A4 01 8E 00 A9
M0738 = 01 8F 00 AA 01 90 00 B3
M0740 = 01 91 00 B4 01 92 00 BF
M0748 = 01 93 00 BA 01 94 00 BE
M0750 = 01 95 00 C4 01 96 00 C0
M0758 = 01 97 00 C3 01 98 00 C1
M0760 = 01 99 00 CA 01 9A 00 CC
M0768 = 01 9B 00 CE 01 9C 00 CC
M0770 = 01 9D 00 CB 01 9E 00 D0
M0778 = 01 9F 00 C6 01 A0 00 C7
M0780 = 01 A1 00 C5 01 A2 00 CC
M0788 = 01 A3 00 CA 01 A4 00 C8
M0790 = 01 A5 00 BC 01 A6 00 BB
M0798 = 01 A7 00 BB 01 A8 00 BE
M07A0 = 01 A9 00 C1 01 AA 00 BA
M07A8 = 01 AB 00 BB 01 AC 00 B6
M07B0 = 01 AD 00 B2 01 AE 00 B4
M07B8 = 01 AF 00 B4 01 B0 00 B0
M07C0 = 01 B1 00 B3 01 B2 00 B1
M07C8 = 01 B3 00 B1 01 B4 00 AE
M07D0 = 01 B5 00 AD 01 B6 00 AC
M07D8 = 01 B7 00 A5 01 B8 00 A3
M07E0 = 01 B9 00 A0 01 BA 00 9D
M07E8 = 01 BB 00 A5 01 BC 00 9F
M07F0 = 01 BD 00 A2 01 BE 00 9F
M07F8 = 01 BF 00 9E 01 C0 00 9D
M0800 = 01 C1 00 9E 01 C2 00 98
M0808 = 01 C3 00 9D 01 C4 00 95
M0810 = 01 C5 00 93 01 C6 00 92
M0818 = 01 C7 00 95 01 C8 00 98
M0820 = 01 C9 00 91 01 CA 00 94
M0828 = 01 CB 00 92 01 CC 00 8A
M0830 = 01 CD 00 85 01 CE 00 85
M0838 = 01 CF 00 82 01 D0 00 84
M0840 = 01 D1 00 85 01 D2 00 85
M0848 = 01 D3 00 8D 01 D4 00 83
M0850 = 01 D5 00 83 01 D6 00 7D
M0858 = 01 D7 00 83 01 D8 00 7C
M0860 = 01 D9 00 73 01 DA 00 78
M0868 = 01 DB 00 7E 01 DC 00 75
M0870 = 01 DD 00 73 01 DE 00 6E
M0878 = 01 DF 00 6B 01 E0 00 65
M0880 = 01 E1 00 7A 01 E2 00 6D
M0888 = 01 E3 00 69 01 E4 00 69
M0890 = 01 E5 00 61 01 E6 00 5B
M0898 = 01 E7 00 5A 01 E8 00 5C
M08A0 = 01 E9 00 57 01 EA 00 56
M08A8 = 01 EB 00 54 01 EC 00 56
M08B0 = 01 ED 00 55 01 EE 00 50
M08B8 = 01 EF 00 4A 01 F0 00 4B
M08C0 = 01 F1 00 47 01 F2 00 45
M08C8 = 01 F3 00 48 01 F4 00 3E
M08D0 = 01 F5 00 40 01 F6 00 3F
M08D8 = 01 F7 00 34 01 F8 00 42
M08E0 = 01 F9 00 31 01 FA 00 38
M08E8 = 01 FB 00 37 01 FC 00 38
M08F0 = 01 FD 00 30 01 FE 00 2F
M08F8 = 01 FF 00 32 02 00 00 29
M0900 = 02 01 00 22 02 02 00 1F
M0908 = 02 03 00 1C 02 04 00 20
M0910 = 02 05 00 1C 02 06 00 13
M0918 = 02 07 00 13 02 08 00 12
M0920 = 02 09 00 0C 02 0A 00 0D
M0928 = 02 0B 00 0A 02 0C 00 09
M0930 = 02 0D 00 07 02 0E 00 06
M0938 = 02 0F 00 05 02 10 00 03
M0940 = 02 11 00 01 02 12 00 00
M0948 = 02 13 00 00 02 14 00 00
stop
&detach
&quit
```

FIGURE D.2 DATA FILE AS IT SHOULD APPEAR BEFORE TRANSFERRING TO MULTICS

```
DATA PLOT DATA GENERATOR,V4
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

                  0000  PLOT4    ORG   0
                        *
                                 TITLE 'DATA PLOT DATA GENERATOR,V4'
                        *
                        *  THIS IS THE FOLLOW-ON SOFTWARE TO PLTT2
                        *  FOR GENERATING X-Y PAIRS TO EVALUATE
                        *  TEST PATTERNS TO BE USED BY THE AUTO-
                        *  MATIC THRESHOLD SEQUENCE.
                        *
                        *  APPROXIMATE RAM LOCATIONS ARE DISPLAYED
                        *  ON THE SCREEN WHERE SIGNIFICANT DATA
                        *  STARTS.
                        *
                        *  WRITTEN BY CAPT B.J. STANTON, 22 JUN 82.
                        *
                        *  SENSE SWITCH FUNCTIONS:
                        *
                        * #          DOWN               UP
                        *-----------------------------------------
                        * 4   NORMAL OPERATION   RETURN TO DOS4
                        * 5   HOLD AT BEGINNING  TAKE DATA
                        * 6   HOLD AT END        RETURN TO BEGINNING
                        *-----------------------------------------
                        *
                        *
                  0000  THRSINL  EQU   H'00'     THRESHOLD LOW INIT.
                  0000  THRSINH  EQU   H'00'     THRESHOLD HI  INIT.
                  0080  VCRSET   EQU   H'80'     DIG VIDEO CNT RESET
                  0003  THRMAX   EQU   H'03'     MAX THRESHOLD VALUE
                  0100  DATBUF   EQU   H'100'    1ST MEMORY LOCATION
                  0004  F1       EQU   4
                  0002  F2       EQU   2
                  0003  F3       EQU   3
                  0005  VLB      EQU   5
                  0006  DLY      EQU   6
                        *
                        *
      0000 2A0100 0100  INIT     DCI   DATBUF    INITIALIZE DATA BUF
      0003 2000                  LI    THRSINL   INITIALIZE THRESHOLD
      0005 50                    LR    0,A       COUNTERS
      0006 2000                  LI    THRSINH   R0 IS LOW BYTE
      0008 51                    LR    1,A       R1 IS HI  BYTE
      0009 70                    CLR
      000A 54                    LR    F1,A
      000B 52                    LR    F2,A
      000C 53                    LR    F3,A
      000D 201E                  LI    D'30'
      000F 56                    LR    DLY,A
                        *
      0010 70           STARTER  CLR             HOLD
      0011 B0                    OUTS  0         UNTIL SENSE 5
      0012 A0                    INS   0         IS PLACED UP.
      0013 2120                  NI    H'20'
      0015 84FA   0010           BZ    STARTER
                        *
                        *  CALL SUBROUTINE FSTLN, 12/80 BY R.L.W.
                        *  TO TEST FOR FALLING EDGE OF PRINTLINE.
                        *
      0017 2800B2 00B2           PI    FSTLN
      001A 2080         RVC      LI    VCRSET    RESET VIDEO COUNT
      001C 2713                  OUT   H'13'
```

```
DATA PLOT DATA GENERATOR,V4
ERRS  LOC OBJECT ADDR LINE              SOURCE STATEMENT

     001E 70          0062            CLR
     001F 2713        0063            OUT   H'13'
                      0064  *
     0021 40          0065  INCTHR    LR    A,0       INCREMENT LOWER
     0022 1F          0066            INC             THRESHOLD BYTE
     0023 50          0067            LR    0,A
     0024 920C   0031 0068            BNC   OUTTHR
     0026 41          0069            LR    A,1       INCREMENT UPPER
     0027 1F          0070            INC             THRESHOLD BYTE
     0028 51          0071            LR    1,A      WITH CARRY
     0029 2503        0072            CI    THRMAX    TEST FOR MAX
     002B 9405   0031 0073            BNZ   OUTTHR    THRESHOLD VALUE
     002D 70          0074            CLR             (GIVES MIN THRES-
     002E 51          0075            LR    1,A       HOLD VOLTAGE)
     002F 906E   009E 0076            BR    RESET
                      0077  *
     0031 40          0078  OUTTHR    LR    A,0       UPDATE THRESHOLD
     0032 2712        0079            OUT   H'12'     VALUE THROUGH
     0034 41          0080            LR    A,1       PORTS 12 AND 13
     0035 2713        0081            OUT   H'13'
     0037 280082 0082 0082            PI    FSTLN     TEST FOR END OF
                      0083  *                         PRINTLINE
     003A 41          0084            LR    A,1       STORE THRESHOLD
     003B 17          0085            ST              UPPER BYTE
     003C 40          0086            LR    A,0       STORE THRESHOLD
     003D 17          0087            ST              LOWER BYTE
     003E 70          0088            CLR
     003F 2711        0089            OUT   H'11'     STORE DIGITAL VIDEO
     0041 2611        0090            IN    H'11'     UPPER BYTE
     0043 18          0091            COM
     0044 17          0092            ST
     0045 70          0093            CLR
     0046 2710        0094            OUT   H'10'     STORE DIGITAL VIDEO
     0048 2610        0095            IN    H'10'     LOWER BYTE
     004A 18          0096            COM
     004B 17          0097            ST
     004C 55          0098            LR    VLB,A     ALSO STORE IN 55
     004D 44          0099            LR    A,F1
     004E 2400        0100            AI    0         TEST FLAG 1
     0050 941E   006F 0101            BNZ   @1
     0052 45          0102            LR    A,VLB
     0053 2102        0103            NI    H'02'     TEST FOR CHANGE IN
     0055 84C4   001A 0104            BZ    RVC       VIDEO COUNT
     0057 71          0105            LIS   1
     0058 54          0106            LR    F1,A      CHANGE FLAG 1 TO 1
     0059 2C          0107            XDC
     005A 2A0100 0100 0108            DCI   M1+21
     005D 2800C4 00C4 0109            PI    SHOW
     0060 2A00E3 00E3 0110            DCI   M1
     0063 40          0111            LR    A,0
     0064 57          0112            LR    7,A
     0065 71          0113            LIS   1
     0066 50          0114            LR    0,A
     0067 283653 3653 0115            PI    H'3653'   DISPLAY ROUTINE
     006A 2C          0116            XDC
     006B 47          0117            LR    A,7       RESTORE COUNT
     006C 50          0118            LR    0,A
     006D 90AC   001A 0119            BR    RVC
                      0120  *
     006F 42          0121  @1        LR    A,F2      TEST FLAG 2
     0070 2400        0122            AI    0
```

```
DATA PLOT DATA GENERATOR,V4
ERRS  LOC OBJECT ADDR LINE           SOURCE STATEMENT

      0072 8423    0096 0123            BZ     32
      0074 43           0124            LR     A,F3        TEST FLAG 3
      0075 2400         0125            AI     0
      0077 94A2    001A 0126            BNZ    RVC
      0079 45           0127            LR     A,VLB
      007A 2400         0128            AI     0           CHECK VIDEO COUNT
      007C 949D    001A 0129            BNZ    RVC         EQUAL TO ZERO
      007E 71           0130            LIS    1
      007F 53           0131            LR     F3,A        SET FLAG 3 TO 1
      0080 2C           0132            XDC
      0081 2A0113 0113  0133            DCI    M2+16
      0084 2800C4 00C4  0134            PI     SHOW
      0087 2A0103 0103  0135            DCI    M2
      008A 40           0136            LR     A,0
      008B 57           0137            LR     7,A         SAVE THRESHOLD COUNT
      008C 71           0138            LIS    1
      008D 50           0139            LR     0,A
      008E 283653 3653  0140            PI     H'3653'
      0091 2C           0141            XDC
      0092 47           0142            LR     A,7
      0093 50           0143            LR     0,A
      0094 9085    001A 0144            BR     RVC
                        0145  *
      0096 36           0146  32        DS     DLY
      0097 9482    001A 0147            BNZ    RVC
      0099 71           0148            LIS    1
      009A 52           0149            LR     F2,A        SET FLAG 2 TO 1
      009B 29001A 001A  0150            JMP    RVC
                        0151  *
                        0152  *
                        0153  *
      009E 70           0154  RESET     CLR                HOLD UNTIL
      009F B0           0155            OUTS   0           SENSE 6 IS PLACED UP
      00A0 A0           0156            INS    0
      00A1 2140         0157            NI     H'40'
      00A3 8404    00A8 0158            BZ     RS2
      00A5 290000 0000  0159            JMP    INIT
      00A8 70           0160  RS2       CLR
      00A9 B0           0161            OUTS   0           CHECK FOR SENSE 4
      00AA A0           0162            INS    0           UP TO RETURN TO
      00AB 2110         0163            NI     H'10'       DOS4
      00AD 84F0    009E 0164            BZ     RESET
      00AF 292330 2330  0165            JMP    H'2330'
                        0166  *
                        0167  * SUBROUTINE FSTLN
                        0168  *
                        0169  * WRITTEN BY R.L. VINCIGUERRA, 12/80.
                        0170  *
                        0171  * THIS SUBROUTINE WAITS FOR THE SIGNAL PRINT-
                        0172  * LINE TO MAKE A FALLING TRANSITION SIGNALLIG
                        0173  * THE END OF A LINE OF VIDEO INFORMATION.
                        0174  * DUE TO AN INVERSION IN THE F8 I/O PORTS,
                        0175  * THIS PROGRAM IS DESIGNED TO CATCH A RISING
                        0176  * TRANSITION.
                        0177  *
                        0178  *
                   0040 0179  ENSENS    EQU    H'40'
                        0180  *
      00B2 2040         0181  FSTLN     LI     ENSENS      ENABLE SENSE INPUTS
      00B4 B5           0182            OUTS   5
      00B5 70           0183  LP1       CLR                LOOP UNTIL FALSE
```

```
DATA PLOT DATA GENERATOR,V4
ERRS  LOC OBJECT ADDR LINE          SOURCE STATEMENT

      00B6 B4                            OUTS  4
      00B7 A4                            INS   4
      00B8 2101                          NI    H'01'
      00BA 94FA    00B5                  BNZ   LP1
      00BC 70                  LP2       CLR                 LOOP UNTIL TRUE
      00BD B4                            OUTS  4
      00BE A4                            INS   4
      00BF 2101                          NI    H'01'
      00C1 84FA    00BC                  BZ    LP2
      00C3 1C                            POP
                               *
                               * END OF SUBROUTINE FSTLN-----------------
                               *
                               * SUBROUTINE TO CONVERT KEY TO ASCII-------
                               *
      00C4 2C                  SHOW      XDC
      00C5 11                            LR    H,DC
      00C6 2C                            XDC
      00C7 4A                            LR    A,10
      00C8 210F                          NI    H'0F'
      00CA 2430                          AI    H'30'
      00CC 2539                          CI    H'39'
      00CE 8103    00D2                  BP    SH1
      00D0 2407                          AI    H'07'
      00D2 17                  SH1       ST
      00D3 4B                            LR    A,11
      00D4 14                            SR    4
      00D5 2430                          AI    H'30'
      00D7 2539                          CI    H'39'
      00D9 8103    00DD                  BP    SH2
      00DB 2407                          AI    H'07'
      00DD 17                  SH2       ST
      00DE 4B                            LR    A,11
      00DF 210F                          NI    H'0F'
      00E1 2430                          AI    H'30'
      00E3 2539                          CI    H'39'
      00E5 8103    00E9                  BP    SH3
      00E7 2407                          AI    H'07'
      00E9 17                  SH3       ST
      00EA 1C                            POP
                               *
                               * END SUBROUTINE SHOW--------------
                               *
      00EB 0016                M1        DC    HL2'0016'
      00ED 444154                        DC    C'DATA STARTS AROUND '
      0100 232323                        DC    C'###'
      0103 0011                M2        DC    HL2'0011'
      0105 444154                        DC    C'DATA STOPS AT ###'
                               *
                               *
                                         END
00 ERRS
```

```
      ∇ADDPLOT1[⎕]∇

    ∇ ADDPLOT1 A;SH;PC;P;V
[1]    ⍝ THIS FUNCTION ACCEPTS A TWO DIMENSIONAL ARRAY
[2]    ⍝ ARRANGED AS X-Y PAIRS, IT AUTOMATICALLY PLOTS THE DATA
[3]    ⍝ TO THE SCALE ESTABLISHED BY ONE OF THE SCALING FUNCTIONS,
[4]    ⍝ THE VIRTUAL GRAPHICS TABLE MUST BE INITIALIZED BY EITHER
[5]    ⍝ SETSCALE OR GRIDSCALE,
[6]    ⍝ THIS FUNCTION MAY BE USED TO PLOT MULTIPLE SETS OF
[7]    ⍝ DATA ALTHOUGH EACH SET WILL BE DRAWN WITH A SOLID LINE,
[8]    ⍝ ALSO NOTE THAT THE RANGES OF THE MULTIPLE SETS
[9]    ⍝ OF DATA MUST BE COMPATIBLE,
[10]   SH ← ⍴A
[11]   P ← LL,(GFSCALE (SF,1))
[12]   PC ← 1
[13]   P ← P,(GFVECTOR (A[PC;] - SXY[;1]),0)
[14] LP: PC ← PC + 1
[15]   P ← P,(GFVECTOR (A[PC;] - A[(PC-1);]),0)
[16]   → (PC ≠ SH[1])/LP
[17]   GFDISPLAYAPPEND (GFARRAY P)
    ∇


      ∇ADDPLOT2[⎕]∇

    ∇ ADDPLOT2 A;SH;PC;P;V
[1]    ⍝ THIS FUNCTION ACCEPTS A TWO-DIMENSIONAL ARRAY
[2]    ⍝ ARRANGED AS X-Y PAIRS AND PLOTS THE DATA ACCORDING
[3]    ⍝ TO THE SCALE ESTABLISHED BY ONE OF THE SCALING FUNCTIONS,
[4]    ⍝ THE VIRTUAL GRAPHICS TABLE MUST BE INITIALIZED BY EITHER
[5]    ⍝ SETSCALE OR GRIDSCALE,
[6]    ⍝ THIS FUNCTION MAY BE USED TO PLOT SUCCESSIVE SETS OF
[7]    ⍝ DATA AS LONG AS THE RANGES ARE COMPATIBLE,
[8]    ⍝ USES DIFFERENT LINETYPES FOR MULTIPLE PLOTS,
[9]    ⍝
[10]   SH ← ⍴A
[11]   P ← LL,(GFSCALE (SF,1)),GFLINETYPE LT
[12]   PC ← 1
[13]   P ← P,(GFSHIFT (A[PC;] - SXY[;1]),0)
[14] LP: PC ← PC + 1
[15]   P ← P,(GFVECTOR (A[PC;] - A[(PC-1);]),0)
[16]   → (PC≠SH[1])/LP
[17]   GFDISPLAYAPPEND (GFARRAY P)
[18]   LT ← LT + 1
    ∇
```

```
∇GRIDSCALE[⎕]∇

    ∇ GRIDSCALE Y;CA;XL;XS;XT;YL;YS;YT;MIN;SF;R;NXT;NYT
      ⍝ THIS FUNCTION INITIALIZES THE VIRTUAL GRAPHICS TABLE
      ⍝ AND DRAWS X AND Y AXES ALONG WITH A GRID ACCORDING TO
      ⍝ THE RANGES MANUALLY INPUT FOR X AND Y. DATA IS MEANT
      ⍝ TO BE PLOTTED BY ADDPLOT1 OR ADDPLOT2.
      ⍝
      ⍝ THE NUMBER OF TICKS ON EACH AXIS CAN BE CONTROLLED
      ⍝ BY STORING THE DESIRED NUMBER IN NXT AND NYT.
      ⍝
      ⍝ BEFORE CALLING THIS  FUNCTION,THE  DESIRED LABELS
      ⍝ MUST BE ESTABLISHED IN THE FOLLOWING GLOBAL VARIABLES:
      ⍝ 'LABEL' SHOULD CONTAIN THE LABEL FOR THE GRAPH
      ⍝ 'XLABEL' SHOULD CONTAIN THE LABEL FOR THE X-AXIS
      ⍝ 'YLABEL' SHOULD CONTAIN THE LABEL FOR THE Y-AXIS
      ⍝
      NXT ← 8
      NYT ← 5
      GFINIT
      SXY ← (2 2⍴(X,Y))
      MIN ← SXY[;1]
      R ← (SXY[;2] - SXY[;1])
      SF ← 900 ÷ R
      LL ← GFSETPOSITION ¯400 ¯400 0
      P ← GFSETPOSITION ¯400 500 0
      LT ← CA ← 0
      XL ← 0 ¯900 0
      XS ← (900÷NXT),(0 0)
      XT ← 0 ¯10 0
    L1: P ← P,(GFLINETYPE LT),(GFVECTOR XL),GFSHIFT XT
      P ← P,(2 GFTEXT ((FREC R[1])⍕(MIN[1] + R[1]×CA÷NXT)))
      P ← P,(GFSHIFT (XS-XL+XT))
      CA ← CA + 1
      LT ← 2
      → (CA ≠ (NXT + 1))/L1
      P ← P,(GFSETPOSITION 500 ¯400 0)
      YL ← ¯900 0 0
      YS ← 0,(900÷NYT),0
      YT ← ¯10 0 0
      LT ← CA ← 0
    L2: P ← P,(GFLINETYPE LT),(GFVECTOR YL), GFSHIFT YT
      P ← P,(6 GFTEXT ((FREC R[2])⍕(MIN[2] +R[2]×CA÷NYT)))
      P ← P,GFSHIFT (YS-YL+YT)
      CA ← CA +1
      LT ← 2
      → (CA≠ (NYT + 1))/L2
      P ← P,(GFSETPOSITION 20 ¯475 0),(5 GFTEXT LABEL)
      P ← P,(GFSETPOSITION ¯500 450 0),(4 GFTEXT YLABEL)
      P ← P,(GFSETPOSITION 450 ¯450 0),(5 GFTEXT XLABEL)
      GFDISPLAY (GFARRAY P)
      LT ← 0
    ∇
```

```
      ∇INPUT2[⎕]∇

    ∇ INPUT2 ;XYDAT;NEWLN
[1]    ⍝ THIS FUNCTION ACCEPTS ASCII DATA ON A LINE-BY-LINE
[2]    ⍝ BASIS.  EACH LINE MUST BE AT LEAST 10 CHARACTERS LONG.
[3]    ⍝ THE FUNCTION WILL TERMINATE ON ENCOUNTERING A LINE
[4]    ⍝ SHORTER THAN 10 CHARACTERS.  DATA IS LOADED INTO THE
[5]    ⍝ ONE-DIMENSIONAL GLOBAL ARRAY; CHAR.
[6]    COUNT←1
[7]    XYDAT←⍞
[8]   LP: NEWLN←⍞
[9]    →((⍴NEWLN)<10)/STOP
[10]   XYDAT←XYDAT,NEWLN
[11]   COUNT←COUNT+1
[12]   →LP
[13]  STOP: CHAR←XYDAT
[14]   'FILE TRANSFER COMPLETE'
    ∇


      ∇CONVERT[⎕]∇

    ∇ XY ← CONVERT ;R;CN;N;I;A;DEC;CVT;⎕IO
[1]    ⍝ THIS FUNCTION IS TAILORED TO CONVERT ASCII DATA
[2]    ⍝ FROM THE F8 'DISPLAY MEMORY' FORMAT TO A
[3]    ⍝ TWO-DIMENSIONAL ARRAY OF X-Y DATA POINTS.  DATA
[4]    ⍝ MUST HAVE BEEN READ INTO THE WORKSPACE WITH THE
[5]    ⍝ FUNCTION, INPUT2.
[6]    R←(COUNT,31)⍴CHAR
[7]    N←R[;9 10 12 13 15 16 18 19 21 22 24 25 27 28 30 31]
[8]    CN←((COUNT×4),4)⍴N
[9]    CVT←'0123456789ABCDEF'
[10]   ⎕IO←0
[11]   I←CVT⍳CN
[12]   ⎕IO←1
[13]   A←1
[14]   DEC←16⊥I[A;]
[15]  LP1: A←A+1
[16]   DEC←DEC,(16⊥I[A;])
[17]   →(A<(COUNT×4))/LP1
[18]   XY←((COUNT×2),2)⍴DEC
[19]   CHAR ← 0
    ∇
```

```
      ∇PLOTGRIDSCALE[⎕]∇

    ∇ PLOTGRIDSCALE A
[1]    ⍝ THIS FUNCTION IS A SELF-CONTAINED PLOTTING FUNCTION
[2]    ⍝ THAT AUTOMATICALLY SCALES THE X AND Y AXES ACCORDING
[3]    ⍝ TO THE RANGES OF THE X-Y DATA. GRIDS ARE INCLUDED.
[4]    ⍝
[5]    SXY ← (2 2⍴(⌊/A[;1]),(⌈/A[;1]),(⌊/A[;2]),(⌈/A[;2]))
[6]    SXY[1;] GRIDSCALE SXY[2;]
[7]    ADDPLOT1 A
    ∇


      ∇PLOTSCALE[⎕]∇

    ∇ PLOTSCALE A
[1]    ⍝ THIS FUNCTION IS A SELF-CONTAINED PLOTTING FUNCTION
[2]    ⍝ THAT AUTOMATICALLY SCALES THE X AND Y AXES ACCORDING
[3]    ⍝ TO THE RANGES OF THE X-Y DATA.  NO GRIDS ARE DRAWN.
[4]    ⍝
[5]    SXY ← (2 2⍴(⌊/A[;1]),(⌈/A[;1]),(⌊/A[;2]),(⌈/A[;2]))
[6]    SXY[1;] SETSCALE SXY[2;]
[7]    ADDPLOT1 A
    ∇


      ∇PREC[⎕]∇

    ∇ N ← PREC R
[1]    ⍝ THIS FUNCTION IS CALLED BY THE SCALE FUNCTION TO
[2]    ⍝ DETERMINE THE PRECISION OF THE X AND Y SCALES.
[3]    →(R>1E4)/S1
[4]    →(R>100)/S2
[5]    →(R > 5)/S3
[6]    →(R ≥ 1)/S4
[7]   S1: N ← ¯2
[8]    → 0
[9]   S2: N ← 0
[10]   → 0
[11]  S3: N ← 1
[12]   → 0
[13]  S4: N ← 2
    ∇
```

```
      ∇RANGE[⎕]∇

    ∇ RANGE A;MAX;R;C
[1]   ⍝ THIS FUNCTION YIELDS THE R[illegible] OF [illegible] AND Y VALUES
[2]   ⍝ AND THE VALUE OF N GENERA[illegible] MTC.
[3]   ⍝ USEFUL [illegible] CHECKING FOR VAL[illegible] DATA [illegible] AFTER
[4]   ⍝ EXECUTING THE FUNCTIONS T[illegible] AND CONVERT.
[5]   ' '
[6]   'MIN AND MAX VALUES OF X ARE ',⍕(⌊/A[;1]),(⌈/A[;1])
[7]   ' '
[8]   MTC ← (⌈/A[;2])
[9]   'MIN AND MAX VALUES OF Y AR[illegible] ',⍕(⌊/A[;2]),MTC)
[10]  ' '
[11]  ' '
[12]  R ← ⍴A
[13]  C ← 1
[14] LOOP: →(MTC = A[C;2])/DISP
[15]  C ← C+1
[16]  → LOOP
[17] DISP: 'THE THRESHOLD VALUE'
[18]  'GENERATING'
[19]  'MTC IS AT N = ',⍕A[C;1]
    ∇


      ∇XYDUMP[⎕]∇

    ∇ PRINT ← XYDUMP A;L;E;C1;C2;S;SP
[1]   ⍝ THIS FUNCTION FORMATS A TWO-DIMENSIONAL DATA
[2]   ⍝ SET FOR PRINTING ON AN 8.5 × 11 PAGE.
[3]   ⍝
[4]   SP ← 300 4⍴' '
[5]   C2 ← 0
[6]   L ← (⍴A)[1]
[7]   S ← ' '
[8]   → (L≥300)/L1
[9]   E← (⍳(300-L))+A[L;1]
[10]  L← ⍴E
[11]  E ← ((L,1)⍴E),(L⍴0)
[12]  A ← A,[1]E
[13] L1:  A← 300 2⍴A
[14]  A ← 5 0 ⍕ A
[15]  A ← A,SP
[16] L2:  C2 ← C2 + 1
[17]  → (C2=61)/L4
[18]  C1 ← 0
[19] L3:  S ← S,A[(C2+C1×60);]
[20]  → (C1=4)/L2
[21]  C1 ← C1 + 1
[22]  → L3
[23] L4:  S ← 1↓S
[24]  S ← 60 70 ⍴S
[25]  PRINT ← S
    ∇
```

```
∇SETSCALE[⎕]∇

∇ Y SETSCALE ;MIN;F;R;XS;XT;YS;YT;CA;NXT;NYT
 ⍝ THIS FUNCTION INITIALIZES THE VIRTUAL GRAPHICS TABLE
 ⍝ AND DRAWS X AND Y AXES ACCORDING TO THE RANGES TAKEN
 ⍝ FOR X AND Y.  NO GRID IS PROVIDED.  DATA IS
 ⍝ MEANT TO BE PLOTTED BY ADDPLOT1 OR ADDPLOT2.
 ⍝
 ⍝ THE NUMBER OF TICKS ON EACH AXIS CAN BE CONTROLLED
 ⍝ BY STORING THE DESIRED NUMBER IN NXT AND NYT.
 ⍝ BEFORE CALLING THIS FUNCTION, THE DESIRED LABELS
 ⍝ MUST BE ESTABLISHED:
 ⍝ GLOBAL VARIABLE 'LABEL' SHOULD CONTAIN THE TITLE OF THE
 ⍝ GRAPH.
 ⍝ GLOBAL VARIABLES 'XLABEL' AND 'YLABEL' ARE THE
 ⍝ LABELS FOR THE TWO AXES.
 ⍝
 NYT ← 5
 NXT ← 8
 GFINIT
 SXY ←(2 2⍴(X,Y))
 MIN ← SXY[;1]
 R ← (SXY[;2] - SXY[;1])
 SF ← 900 ÷ R
 F ← LL ← GFSETPOSITION ¯400 ¯400 0
 F ← F,GFVECTOR 900 0 0
 F ← F,LL,GFVECTOR 0 900 0
 XS ← (900÷NXT),(0 0)
 XT ← 0 ¯10 0
 CA ← 0
 F ← F,LL
L1:  F ← F,(GFVECTOR XT),GFSHIFT XT
 F ← F,(2 GFTEXT ((PREC R[1])⍕(MIN[1] + R[1]×CA÷NXT)))
 F ← F,GFSHIFT (XS - (2 × XT))
 CA ← CA +1
 → (CA≠(NXT + 1))/L1
 YS ← 0,(900÷NYT),0
 YT ← ¯10 0 0
 CA ← 0
 F ← F,LL
L2:  F ← F,(GFVECTOR YT),GFSHIFT YT
 F ← F,(6 GFTEXT ((PREC R[2])⍕(MIN[2] + R[2]×CA÷NYT)))
 F ← F,GFSHIFT (YS - (2 × YT))
 CA ← CA + 1
 → (CA ≠ (NYT + 1))/L2
 F ← F,(GFSETPOSITION 20 ¯475 0),(5 GFTEXT LABEL)
 F ← F,(GFSETPOSITION ¯500 450 0),(4 GFTEXT YLABEL)
 F ← F,(GFSETPOSITION 450 ¯450 0),(5 GFTEXT XLABEL)
 GFDISPLAY (GFARRAY F)
∇
```

```
    ∇CHAOUT[⎕]∇

  ∇ CHAOUT
  ∇

    ∇CHAOUT2[⎕]∇

  ∇ CHAOUT2
[1]   LABEL ← 'ECE A SCANNED UNDER THE SAME CONDITIONS'
[2]   250 550 SETSCALE 0 225
[3]   ADDPLOT A6071
[4]   ADDPLOT A6072
[5]   ADDPLOT A6073
[6]   ADDPLOT A6074
[7]   ADDPLOT A6075
[8]   LABEL ← 'EFFECT OF ONE LAMP VERSUS TWO USING ECE A'
[9]   275 550 SETSCALE 0 225
[10]  ADDPLOT A6063
[11]  ADDPLOT A6064
[12]  LABEL ← 'EFFECT OF OLD VERSUS NEW LAMPS USING ECE A'
[13]  300 625 SETSCALE 0 225
[14]  ADDPLOT A6063
[15]  ADDPLOT A6233
[16]  LABEL ← 'EFFECT OF DIFFERENT PAPER COLORS USING ECE A'
[17]  275 600 SETSCALE 0 225
[18]  ADDPLOT A6062
[19]  ADDPLOT A6066
[20]  ADDPLOT A606A
[21]  ADDPLOT A606D
[22]  LABEL ← 'EFFECT OF DIFFERENT COLORS OF FLUORESCENT LIGHTS USING ECE
[23]  275 625 SETSCALE 0 225
[24]  ADDPLOT A6231
[25]  ADDPLOT A6232
[26]  ADDPLOT A6233
[27]  LABEL ← 'ECE B'
[28]  225 650 SETSCALE 0 475
[29]  ADDPLOT B6062
  ∇
```

APPENDIX E

MODIFIED SCANNER CIRCUITS

This Appendix contains the documentation for all changes made to the scanner circuitry along with the pin connections for the new F8 I/O ports 10 through 13 (hex). The THRESHOLD LEVEL GENERATOR (TLG), Video A-to-D Converter, and VIDEO COUNTERS are located on the VIDEO DETECTION AND THRESHOLDING board. The old Video A-to-D Converter and manual threshold circuit were removed from the TIMING AND PROCESSING board.

Although no additional circuits were changed, it is also noted here that during the course of this project, severe clocking interference necessitated the relocation of several circuit boards that use the high-frequency clock signal generated on the CCD board. Specifically, the following boards were mounted on the top of the mechanical moving assembly of the scanner to minimize the lengths of the leads carrying clocking signals:

1. SYNCHRONIZED LINE-FREQUENCY GENERATOR
2. F8 INTERFACE BOARD NUMBER 4
3. TIMING AND PROCESSING
4. VIDEO DETECTION AND THRESHOLDING

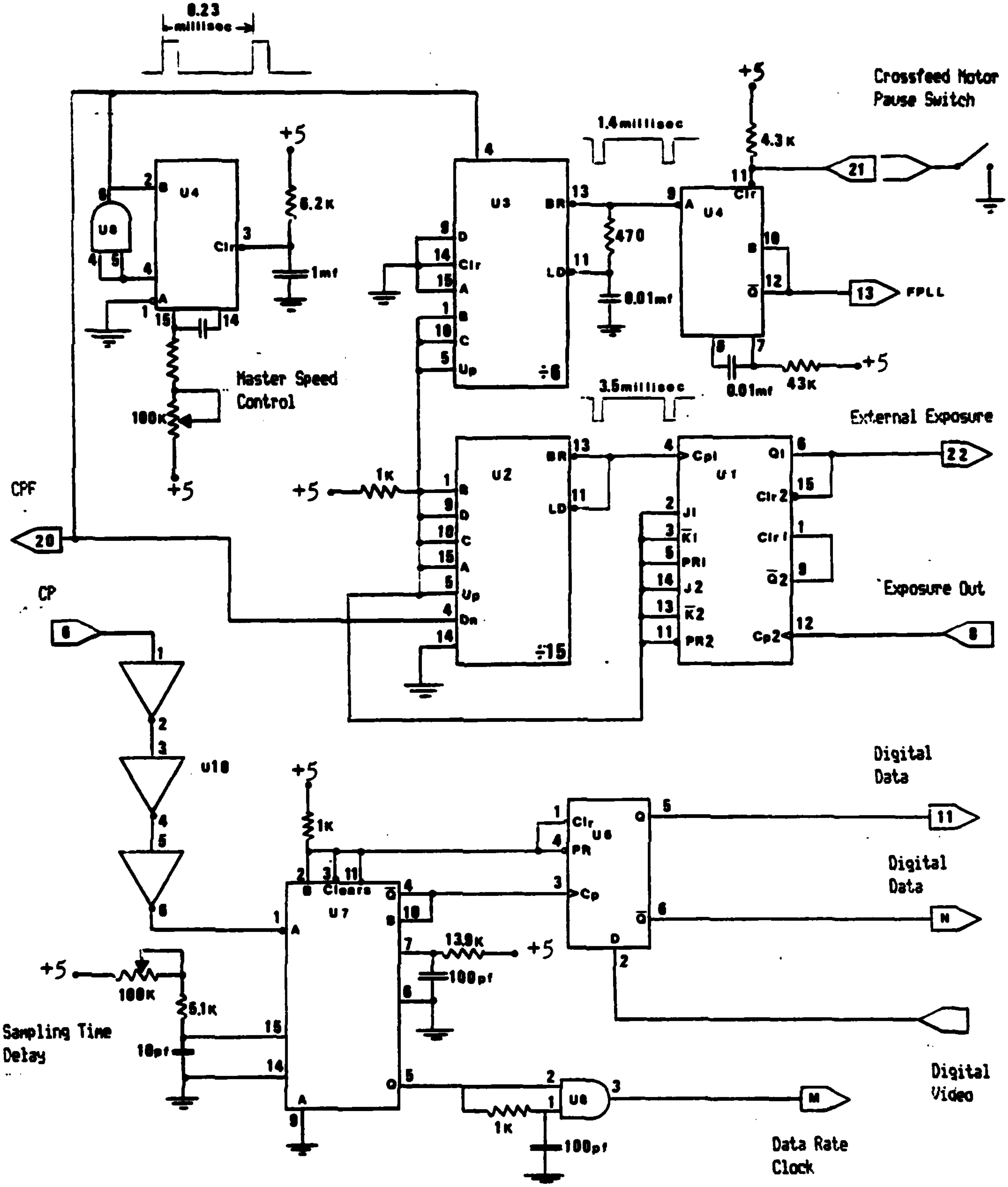
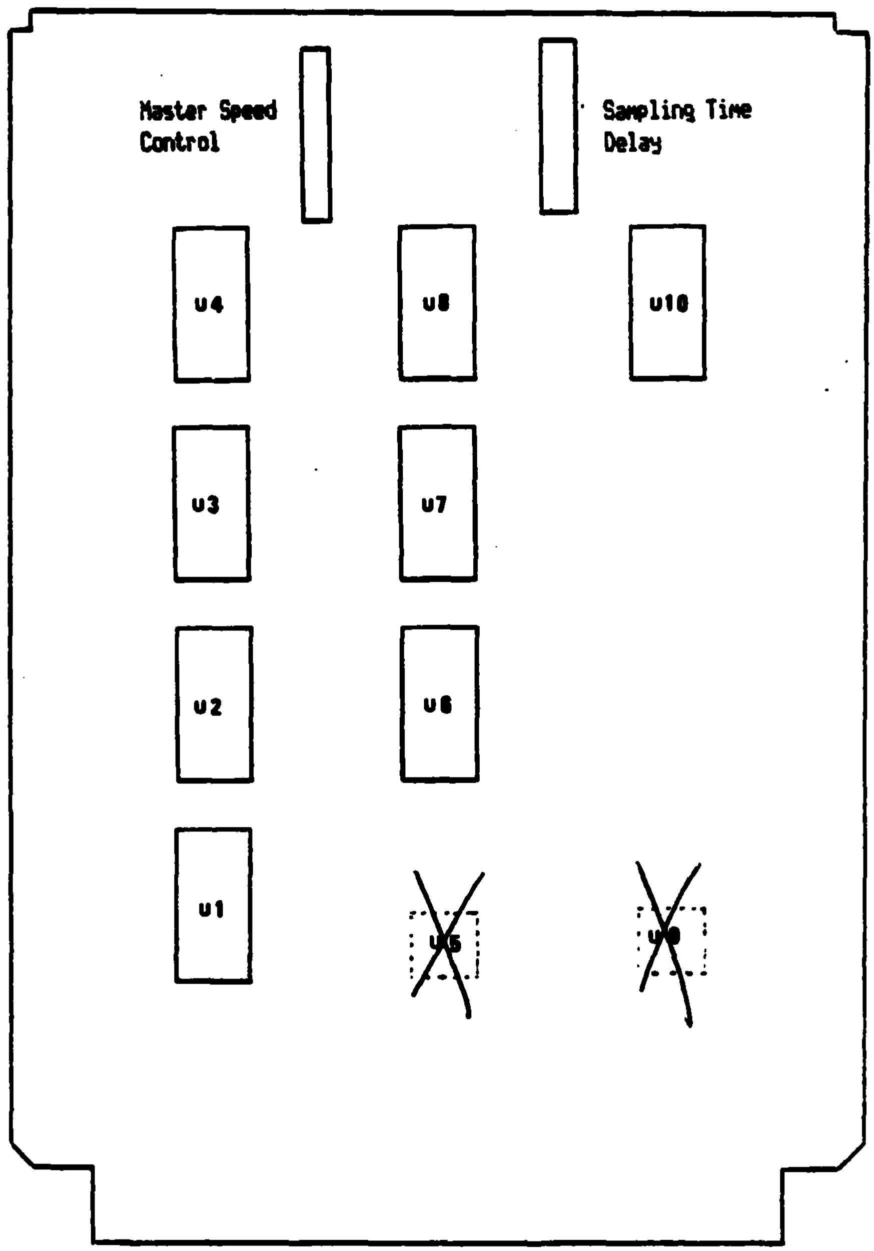
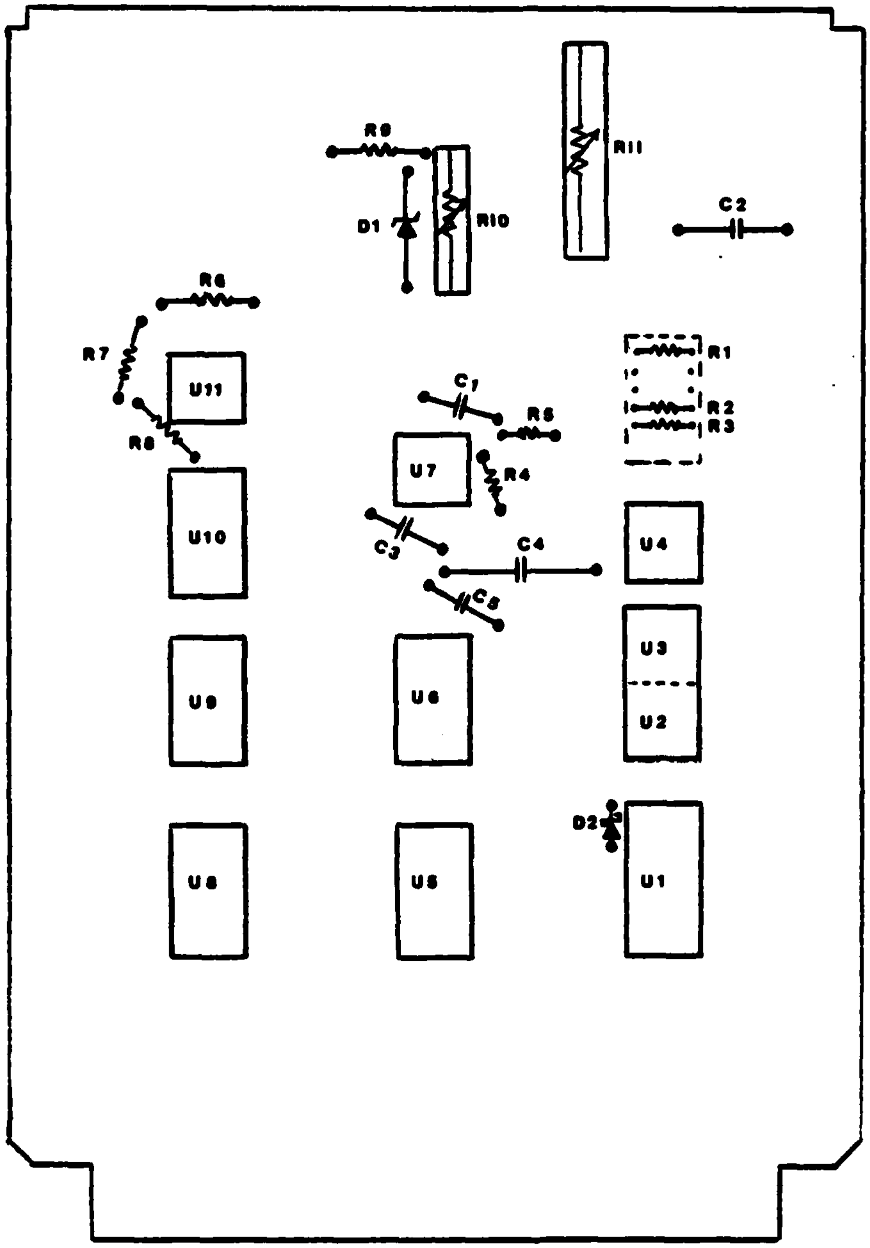


FIGURE E.1 TIMING AND PROCESSING CIRCUIT DIAGRAM
Revision 2, June 1982
(U5 and U9 Removed)



U1 = 74LS109
U2 = 74LS193
U3 = 74LS193
U4 = 74LS123
U6 = 74LS74
U7 = 74LS123
U8 = 74LS08
U10 = 74LS14

FIGURE E.2 TIMING AND PROCESSING CIRCUIT BOARD LAYOUT
Revision 2, June 1982
(U5 and U9 Removed)



C1 = 0.01 Microfarads
C2 = 0.01 Microfarads
C3 = 47 Microfarads
C4 = 0.01 Microfarads
D1 = 13-Volt Zener
D2 = HP5082-2811
R1 = 5K Ohms
R2 = 6K Ohms
R3 = 1K Ohms
R4 = 560 Ohms
R5 = 270 Ohms
R6 = 750 Ohms
R7 = 3.6K Ohms
R8 = 3.6K Ohms
R9 = 560 Ohms
R10 = 5K Ohms
R11 = 500K Ohms
U1 = AD7533
U2 = 741
U3 = 741
U4 = 741
U5 = 74LS04
U6 = 74LS04
U7 = LM311
U8 = 74LS393
U9 = 74LS393
U10 = 74LS00
U11 = LM311

FIGURE E.3 VIDEO DETECTION AND THRESHOLDING CIRCUIT BOARD LAYOUT

VIDEO DETECTION AND THRESHOLDING BOARD

PIN CONNECTIONS

A	+15 Volts	1	N Value Bit 1
B	PRINTLINE In	2	N Value Bit 2
C	Digital Video Out	3	N Value Bit 3
D		4	N Value Bit 4
E		5	N Value Bit 5
F		6	N Value Bit 6
H		7	N Value Bit 7
J		8	N Value Bit 8
K		9	N Value Bit 9
L	+5 Volts	10	N Value Bit 10
M	MTC Clear	11	VTC Bit 1
N	VTC Bit 16	12	VTC Bit 2
P	VTC Bit 15	13	VTC Bit 3
R	VTC Bit 14	14	VTC Bit 4
S	VTC Bit 13	15	VTC Bit 5
T	Analog Video In	16	VTC Bit 6
U		17	VTC Bit 7
V	-15 Volts	18	VTC Bit 8
W		19	VTC Bit 9
X		20	VTC Bit 10
Y		21	VTC Bit 11
Z	Master Ground	22	VTC Bit 12

TIMING AND PROCESSING BOARD

PIN CONNECTIONS

A	+5 Volts	1	+5 Volts
B	Ground	2	Ground
C		3	
D		4	
E		5	Digital Video In
F		6	CP
H		7	
J		8	EXPOSURE OUT
K		9	
L		10	
M	DATA RATE CLOCK	11	DIGITAL DATA
N	DIGITAL DATA	12	
P		13	FPLL
R		14	
S		15	
T		16	
U		17	
V		18	
W		19	
X		20	Test Point
Y		21	
Z		22	EXTERNAL EXPOSURE

NEW F8 I/O PORT PIN ASSIGNMENTS

Port Address	Pin Connections (LSB to MSB)							
10	1	2	3	4	5	6	7	8
11	10	11	12	13	14	15	16	17
12	Z	Y	X	W	V	U	T	S
13	P	N	M	L	K	J	H	F

END

FILMED

3-83

DTIC